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Environment Protecting Concepts of Beef Cattle Feedlot Wastes Management

Robert S Kerr Environmental Research Lab, Ada, Okla

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The function of the manual in this report to serve as a guide to insure consideration and incorporation of pertinent environmental pollution controls in the design and operation of beef cattle feedlots. It has been designed to serve as a reference source for the more detailed information contained in published literature on feedlot design and operation. In addition, the precepts presented in this manual are applicable to other segments of the animal industry.

The design and operation of a successful feedlot are the result of evaluating a myriad of pertinent factors. The authors and editor have considered a majority of these factors but have limited the text of this manual to the environmental concepts affecting a feedlot.

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ENVIRONMENT PROTECTING CONCEPTS
OF
BEEF CATTLE FEEDLOT WASTES MANAGEMENT

by

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EPA REVIEW NOTICE

This report has been reviewed by the Office of Research and Development, EPA, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

The function of this manual is to serve as a guide to insure consideration and incorporation of pertinent environmental pollution controls in the design and operation of beef cattle feedlots. It has been designed to serve as a reference source for the more detailed information contained in published literature on feedlot design and operation. In addition, the precepts presented in this manual are applicable to other segments of the animal industry.

The design and operation of a successful feedlot are the result of evaluating a myriad of pertinent factors. The authors and editor have considered a majority of these factors but have limited the text of this manual to the environmental concepts affecting a feedlot.

As such, this manual is not a guideline, effluent limitation publication, or compendium of regulations, although these are referenced for the convenience of those readers concerned with the legal or regulatory aspects of animal feedlot design and management.

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SECTION I

INTRODUCTION

The beef feeding industry stands today at a crossroad. On one hand, advances in nutrition, breeding, animal health, and mechanization have substantially improved labor and feed efficiencies. On the other, inflation, increased intra-industry competition, growth of competitive protein sources, regulation of growth promoters, and the need for environmental protection threaten to reduce the narrow profit margin of the feeder. Cognizant of these facts, the National Animal Feedlot Wastes Research Program of the Environmental Protection Agency has as its goal the solution of environmental problems of the feeding community, subject to the constraints of economics and practical technology. To this end, the manual is intended as a comprehensive summary of the state of the beef wastes management art. The integrated format is intended to guide the feedlot designer or operator toward the waste management system most suited to his individual requirements and to provide the design and economic information required to make decisions regarding construction, modification, and waste management of his system.

FIGURE I-1. A TYPICAL FEEDLOT IN THE WESTERN U.S.

Besides this introductory section, the manual has been divided as follows. Section II sets forth the currently viable options for confinement facilities and details the characteristics of each as related to wastes management, with special attention devoted to designs having good pollution control potential. Section III relates the factors which should be considered in choosing a location for a new feedlot or in modification of an existing lot in order to avoid many of the pollution-related problems of the industry. Sections IV, V and VI discuss system components presently considered for processing and handling of solid manure, slurries, and liquid runoff, respectively; characteristics, design procedure, and management considerations are detailed for each component. Section VII provides information for economic comparison of alternative systems. Finally, Section VIII presents suggestions for coexistence of the feeding industry with society. Since the technology of animal waste management is in flux, a looseleaf format for the manual has been chosen, and periodic updating will be made based on advances in the field.

Because of the comprehensiveness of the manual, not all systems or components discussed will be of interest to the individual. It is not intended that it be read from cover to cover, but rather used as a reference volume, to be referred to as need or interest arises. To gain familiarity with the manual, it is suggested that Section II be read in its entirety and that the reader peruse the introduction and table of contents preceding each section. Thereafter, the section headings and tables of contents should be sufficient to guide the reader to the subject at hand.

Several important influences on the beef wastes management problems are not primarily economic or technological, but strongly interact with these aspects. These include trends in consumer preference, growth of environmental appreciation by the public, and local, state, and federal legislation. To examine this interaction and consider the future direction of the industry, a brief historical sketch is in order.

Because of the diverse and changing legislation governing state regulation of livestock feeding operations, no attempt has been made in the manual to summarize all applicable state statutes. A 1970 EPA (1) publication briefly outlines the format of regulations for each state, and enumerates the enforcement agencies and their addresses.

In many states, feedlot operation is regulated under general pollution statutes; in the major beef feeding states, however, specific feedlot regulations have been imposed. In general, these regulations define: (a) terms used in confined feeding operations; (b) conditions under which registration is required; (c) information required for registration; (d) minimum requirements for runoff retention structures and waste management practices; and (e) penalties for violations. Selected provisions of the statutes of Texas, Kansas, and Oklahoma are shown in Table I-1.

At this time, no formal requirements regarding construction and operation of cattle feeding facilities have been issued by federal government agencies. However, the following suggestions should be considered as minimal for the design and construction of feeding enterprises:

1. that a 10 year-24 hour storm, or equivalent, be used for minimum design of all runoff collection and retention facilities;
2. that all runoff collection and storage structures, treatment lagoons and ponds, and other structures for the storage of liquid, solid, and semi-solid wastes, as well as those for storage of ensilage, be constructed to eliminate seepage to ground or surface waters;
3. that all tailwater resulting from irrigation with runoff-carried wastes be retained and/or recycled;
4. that appropriate soil incorporation procedures follow land disposal of all solid and semi-solid manure in order to prevent contamination of runoff from precipitation on the disposal area;
5. that prior to land disposal, appropriate tests be made to determine that contaminants from wastes will not percolate or be leached through the soil to groundwater supplies;
6. that prior to application of wastes to the receptor soils, sufficient investigation and studies be undertaken to insure application rates and total amounts of waste incorporated into the disposal area will not adversely affect present and future usage;

TABLE I-1

SELECTED INFORMATION FROM FEEDLOT LAWS OF THREE BEEF FEEDING STATES

State	Jurisdiction	Regulations Employed	Penalties
KANSAS	1. Lots handling 300 or more cattle.	1. Site inspection.	1. Failure to comply with registration, $50-500.
	2. Any operation using a lagoon as a storage.	2. Specification of waste control and runoff retention structures.	2. Unauthorized discharge into waters of the state, $1000 per day that the offense is maintained.
	3. Any other operation having a water pollution potential.	3. Approval of waste treatment facility design.	
	4. Other operators who wish to come under the regulations.	4. Inspection of completed system.	
OKLAHOMA	Feeding operations with more than 250 head of cattle.	Specification of: 1. Retention reservoir capacities 2. Manure disposal 3. Drainage structures 4. Pest control measures	Fines up to $100 per day and revocation of license.
TEXAS	Cattle feedlots (excluding pasture)	Review of: 1. Waste management systems 2. Wastewater management systems 3. Runoff control systems	1. Fines not less than $50 nor more than $1000 per day or per act of violation. 2. Injunctions.

7. that pollutant concentrations in effluent from treatment processes be sufficiently reduced to protect and enhance the quality of receiving waters under all foreseeable circumstances; and

8. that all techniques for handling, storage, and disposal of ensilage and manure waste derivatives be designed to prevent or reduce odor, noise, and other unaesthetic features.

In addition to the information given in this manual, further details on components or systems discussed may be obtained from the references listed at the end of each section. Structural plans and technical assistance are available from the Cooperative Extension Service of the land grant universities, the Soil Conservation Service, and consulting engineers.

REFERENCES

1. Sweeten, J. M., State Agencies Regulating Confined Animal Feeding Operations. EPA, Division of Technical Operations Open-File Report (TO 01.0.543/1) 37 pp. (1971).

SECTION II

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SECTION II

CLIMATIC DESIGN PARAMETERS AND WASTE MANAGEMENT ALTERNATIVES

Specific feedlot design and waste handling system requirements are dependent on the individual needs of the feeder, characteristics of the site location, and variability of the climate in the immediate region where the facilities are to be constructed. The primary objective of this section is to present feedlot designs, pollution controls, and waste management alternatives to assist the feedlot designer and operator in the reduction of the environmental impact of their industry. This section includes: (a) a brief definition of the three basic feedlot design classes, (b) a brief description of the various climatic variables which are limiting to the use of these designs, (c) a detailed climatological breakdown of the United States as related to the limits of the basic designs, and (d) a detailed presentation of design alternatives available for the basic design classes as related to pollution control. After the climatic region has been determined and the basic alternatives regarding facility type, design requirements, and waste management are evaluated then specific details concerning site selection, waste handling and management designs, economics, and community relations can be ascertained from the succeeding sections.

FEEDLOT DESIGN CLASSES

Feedlot designs are divided into three basic classes: (a) open feedlots, (b) open confinement, and (c) total confinement. Open feedlots are low density lots (50 to 400 sq. ft./animal) with little or no cover or protection for the animals. Open confinement feedlots are medium density lots (30 to 75 sq. ft./animal) which offer protection for the animals, ranging from partially roofed to totally roofed pen areas which are enclosed on three sides. Total confinement feedlots are high density buildings (12 to 30 sq. ft./animal) with controlled environment. Each feedlot class has unique waste management and animal protection characteristics making it desirable in specific climatic areas.

CLIMATIC CONSIDERATIONS TO DESIGN SELECTION

Climatic Variables

Major climatic variables affecting beef cattle performance are air temperature, relative humidity, precipitation, evaporation, solar radiation, and wind. Different climatic zones, as illustrated in Figure II-1, were developed for the use of the three variables which exert the greatest amount of control over feedlot wastes management systems. These zones are based upon 80° F average July temperature line, a 32° F average January temperature line (4) and moisture deficit (annual lake evaporation minus annual precipitation) lines of 10 and 30 inches. The 80° F average July temperature was selected because 80° F appears to be a maximal temperature for optimum beef cattle performance (6). Above this temperature, beef animal production declines for most breeds. The 32° F average January temperature line was selected to keep waste management systems above freezing conditions as much as possible. The 20° F average January temperature line was selected because it appears to be the minimal temperature for optimum beef animal performance.

The 30-inch moisture deficit line was selected primarily on the basis of decided advantages for evaporation of liquids from evaporation ponds, other waste management systems, and feedlot surfaces. With less than a 10-inch moisture deficit, the required surface area for evaporation increases very rapidly, and it becomes more difficult to reduce volumes of excess wastewater. Other climatic factors are integrated in these basic parameters. For instance, solar radiation and wind influence the evaporation rate, solar radiation affects average air temperature, and precipitation and evaporation are included in the moisture deficit lines.

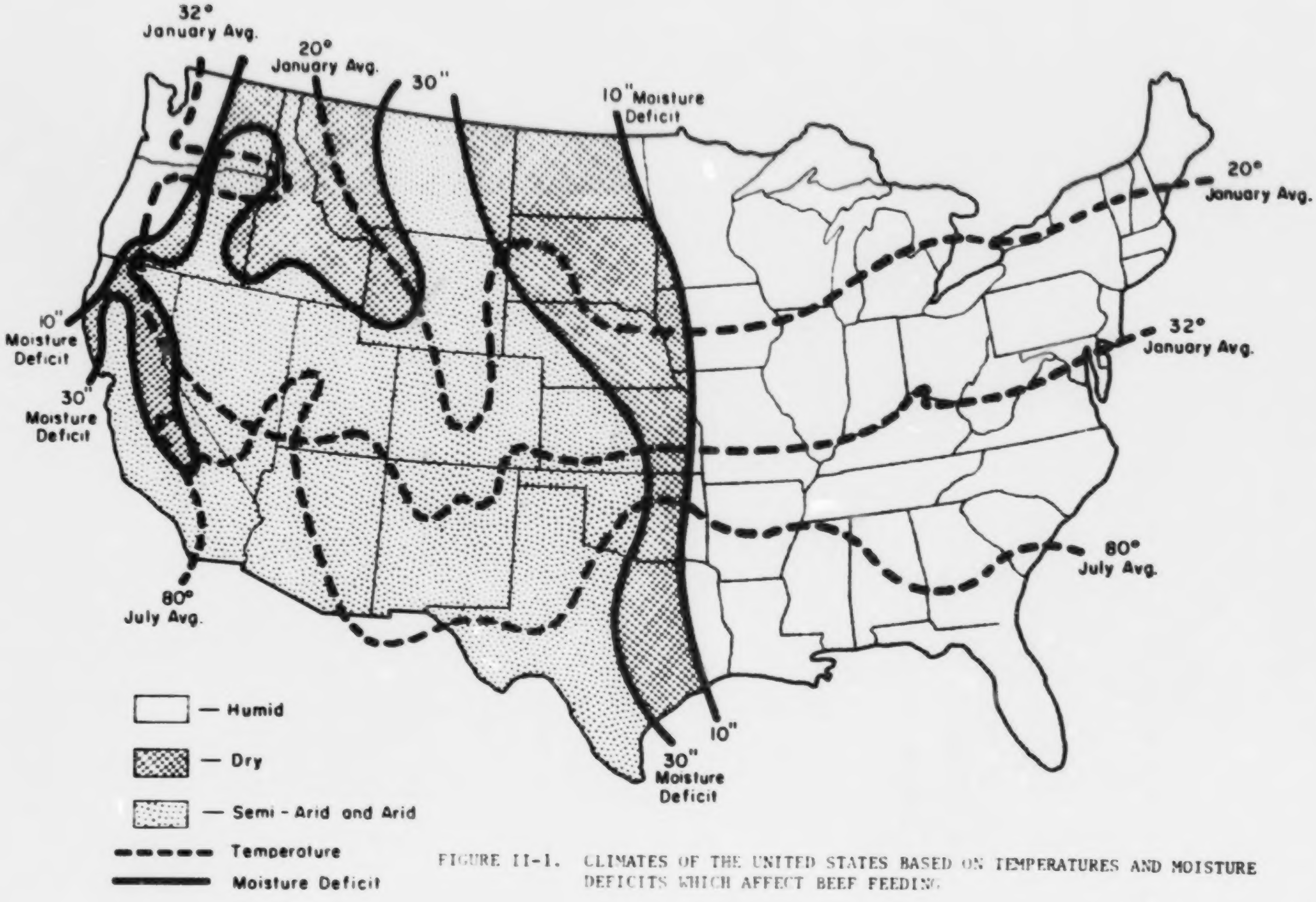

32° January Avg.
20° January Avg.
30"
10" Moisture Deficit
20° January Avg.
32° January Avg.
80° July Avg.
10" Moisture Deficit
30" Moisture Deficit
80° July Avg.
10"
30" Moisture Deficit
— Humid
— Dry
— Semi - Arid and Arid
Temperature
Moisture Deficit

FIGURE II-1. CLIMATES OF THE UNITED STATES BASED ON TEMPERATURES AND MOISTURE DEFICITS WHICH AFFECT BEEF FEEDING

Facility Types and Wastes Management Systems by Climatic Zones

The optimum areas for animal performance in outside open lots and open confinement lots are in the regions which lie between the 80° F average July temperature line and the 20° F average January temperature line (Figure II-2). Outside open lots in these regions are better suited to the semi-arid zones of the High Plains and Southwest which have more than a 30-inch moisture deficit (Figure II-3). There are local conditions within these zones that may not be conducive to open beef feedlots especially in mountainous areas. Dust produced during the dry season is one possible detrimental factor affecting feedlots in these zones.

In the dry reaches of the South Central Plains and Northwest, which are located between the 30-inch and 10-inch moisture deficit lines (Figure II-4), there are limited potentials for evaporation of moisture from feedlot surfaces, and sloppy pen conditions will exist during portions of the year. Modifications, providing the animal protection from the wind during winter months, should be included in areas which have more than a 10-inch moisture deficit and less than 32° F average January temperatures (Northern High Plains and Inter Mountain West--Figure II-5). These areas have freezing problems which affect the performance of waste management systems and livestock. Also, reduced evaporative potentials in these areas during winter months cause sloppy pen conditions when temperatures are above freezing.

As the moisture deficit decreases below 10 inches per year (East Central, Eastern United States and Pacific Northwest--Figure II-6), liquid wastes disposal becomes more difficult. Also, higher humidities and rainfall affect the performance of animals and increase the amount of liquids to be handled from open feedlots. Serious water pollution problems for waste management systems in these areas can result from the application of liquids to wet soils. Thus, open confinement buildings provide better waste management and animal performance by reducing or eliminating the need for liquid waste management systems.

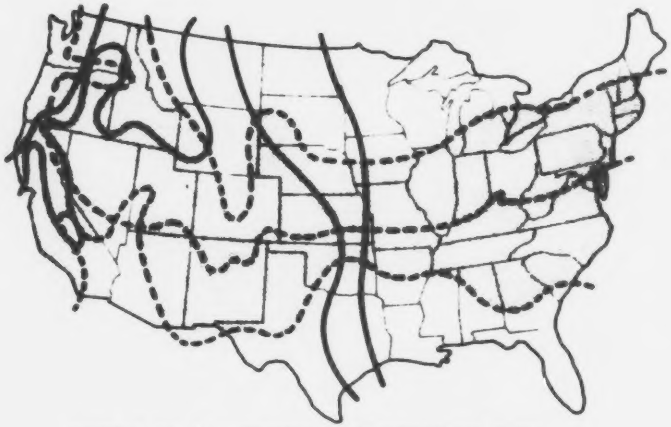


FIGURE II-2. MODERATE TEMPERATURE ZONE

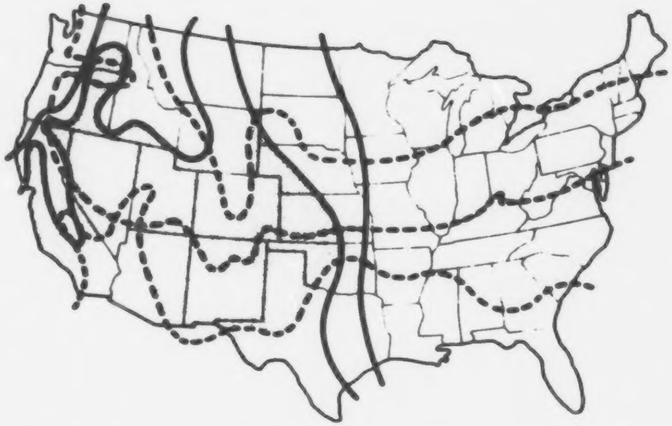


FIGURE II-3. ARID CLIMATES WITH MODERATE TEMPERATURES

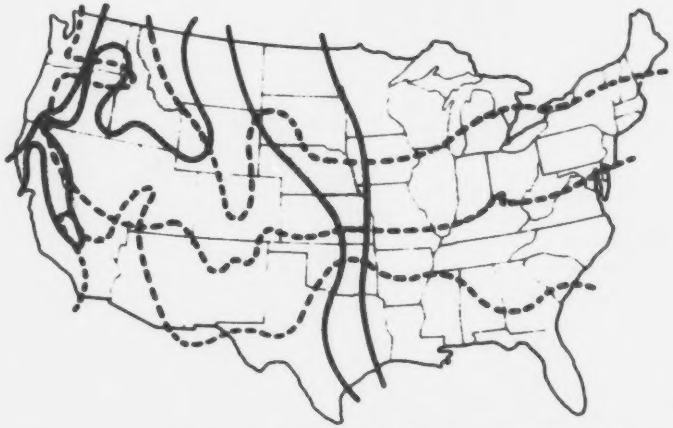


FIGURE II-4. SEMI-ARID CLIMATES WITH MODERATE TEMPERATURES

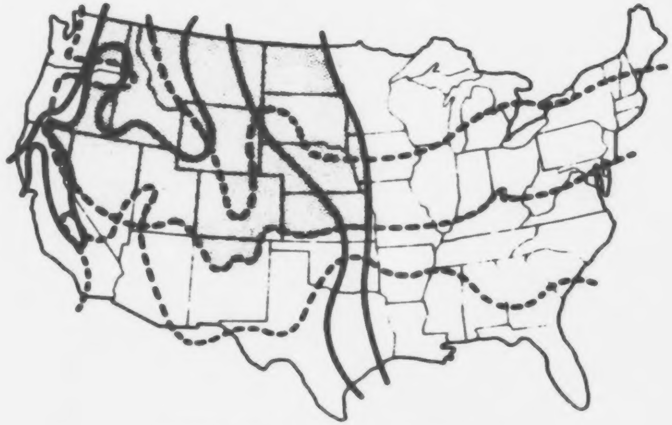


FIGURE II-5. COOL-DRY CLIMATE

Portions of the Corn Belt and Pacific Northwest regions can be classified as cool, humid areas (Figure II-7). These areas are high rainfall areas within the beef cattle temperature comfort zone. Thus, totally covered confinement buildings that have open fronts facing open lots can be used. These will protect the animals and manure covered feedlot surfaces from the high rainfall and the short periods of extreme winter weather.

Southeastern and Northwestern areas which have less than a 10-inch moisture deficit, higher than 32° F average January temperatures and lower than 80° F average July temperatures (Figure II-8) can be classified as warm, sub-humid, and humid. Primarily from the waste control viewpoint, totally covered open confinement facilities which reduce or eliminate the necessity to consider liquid wastes management options are desirable in these areas. The use of fans installed in the buildings will aid air movement in the facility, enhancing animal comfort, and, through increased evaporative potentials, reducing sloppy pen conditions.

There are three examples of typical areas lacking optimal conditions for year-round open feedlot cattle production. First, there are the hot, dry, and semi-arid areas of the Southwest with more than a 30-inch moisture deficit which have higher than 80° F average July temperature (Figure II-9). Modifications in open feedlots are necessary in these areas to provide protection from solar radiation and high temperatures. The second example is the cold, semi-humid and humid zone which lies north of the 20° F average January temperature line and east of the 10-inch moisture deficit line (Upper Great Lakes--Figure II-10). In this zone, insulated total confinement buildings with environmental control have the best potential to provide optimum waste management conditions and beef animal performance. More waste storage area is necessary during the longer winter months for spring application onto fields. The third example, the North Central Plains area north of the 20° F average January temperature line and west of the 10-inch moisture deficit line (Figure II-11) is classified as a cold, dry,

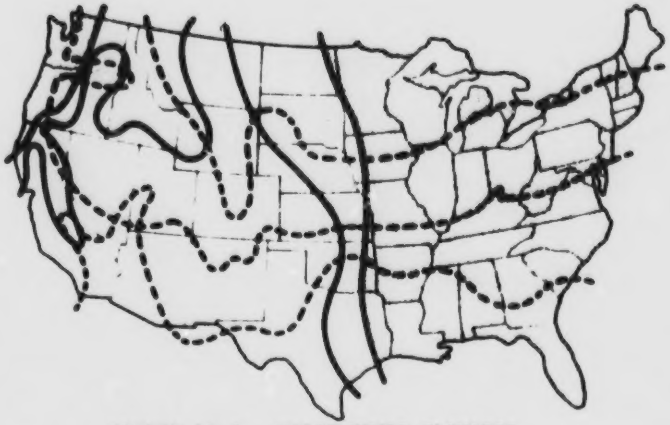


FIGURE II-6. MOIST-HUMID CLIMATES

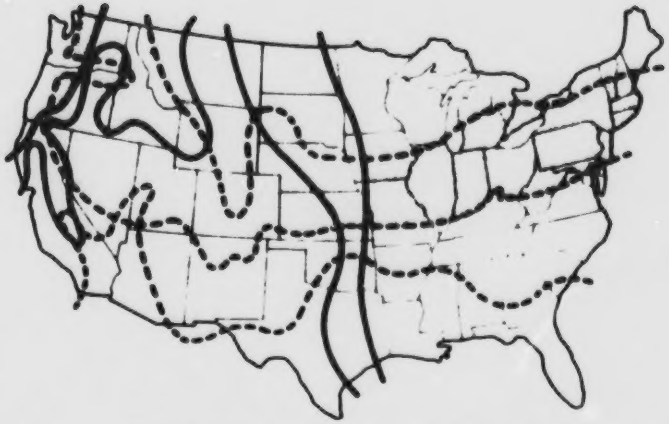


FIGURE II-7. COOL-HUMID CLIMATES

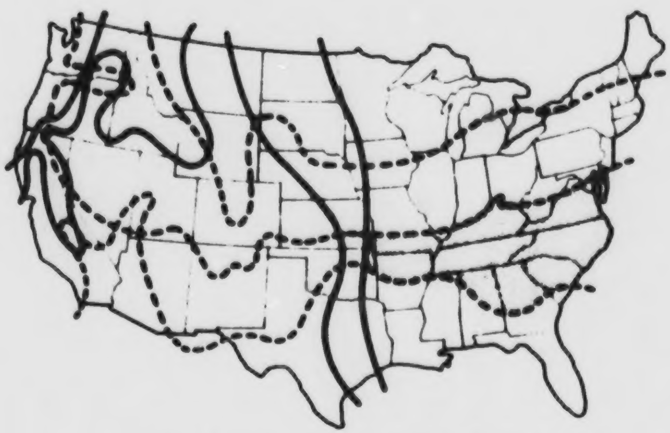


FIGURE II-8. WARM-HUMID CLIMATES

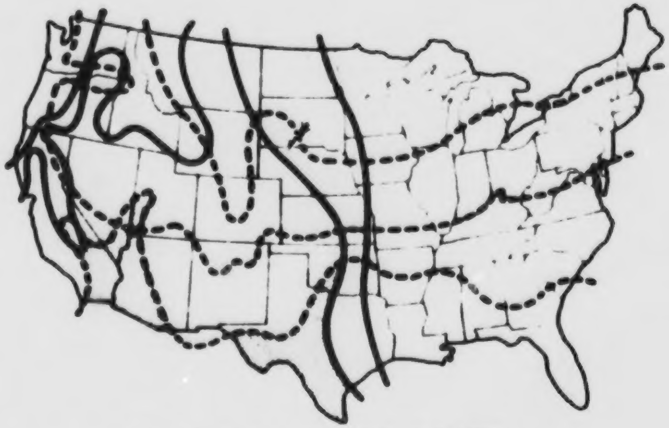


FIGURE II-9. HOT-ARID CLIMATES

and semi-arid zone. This area has some advantages in terms of disposing of excess liquid waste by means of evaporation. However, during the coldest periods of the year when temperatures are below 20° F (which was an indication of the lower limit for comfort of these animals) some protection from wind and cold temperatures should be provided. During other times of the year, beef animal production in outside lots would be favorable. Thus, an open confinement facility with buildings which can be totally enclosed during colder periods can be effectively used in this area.

Beef animal feeding facilities in the southeastern portion of the United States, with negative moisture deficits and average July temperatures above 80° F (Figure II-12) have more difficulties to overcome because of hot, humid climatic conditions which affect the performance of beef animals. The high rainfall causes problems regarding pollution control from open feedlots. In this climate, total confinement buildings with internal environmental control have great potential for reducing or eliminating these problems.

The inter-mountain regions have beef feeding potentials in localized areas. Although these areas have high evaporative potential due to high moisture deficits, most of the region is between the 32° F and the 20° F average January temperature line (Figure II-13). Thus, for a portion of the year, freezing conditions exist which affect the performance of lagoons and surface conditions of the feedlot.

FEEDLOT DESIGN AND WASTE MANAGEMENT ALTERNATIVES

Previously in this section feedlot designs were classified as three basic classes: open feedlots, open-confinement feedlots, and total confinement buildings. These classes are based on the amount of control which may be exerted on the animals' environment. The waste management and design alternatives in many ways are common to two or more of the basic facilities; however, each basic facility class will be individually discussed since the combination of alternatives and components for each class is unique.

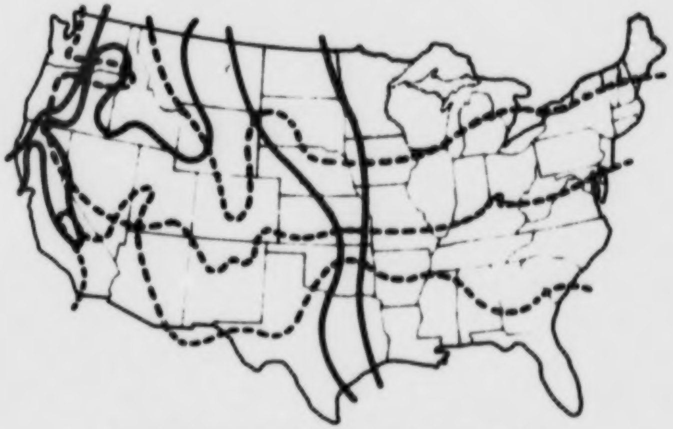


FIGURE II-10. COLD-HUMID CLIMATES

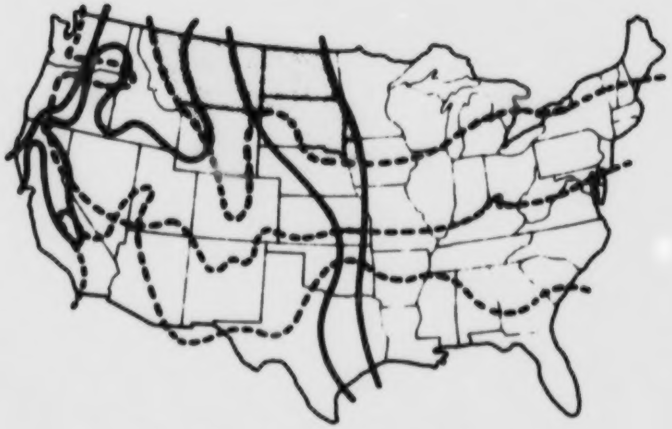


FIGURE II-11. COLD-DRY CLIMATE

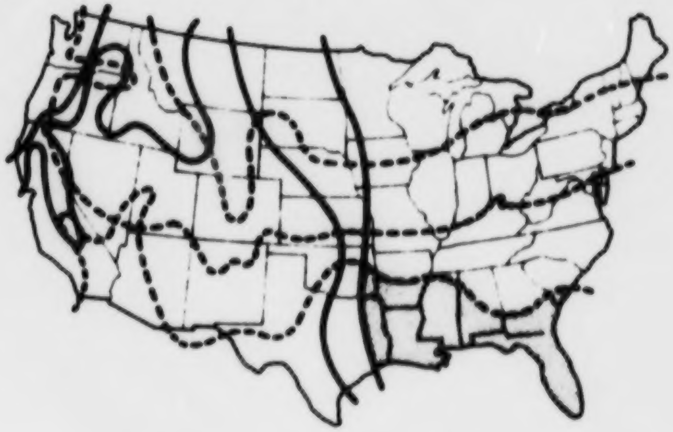


FIGURE II-12. HOT-HUMID CLIMATE

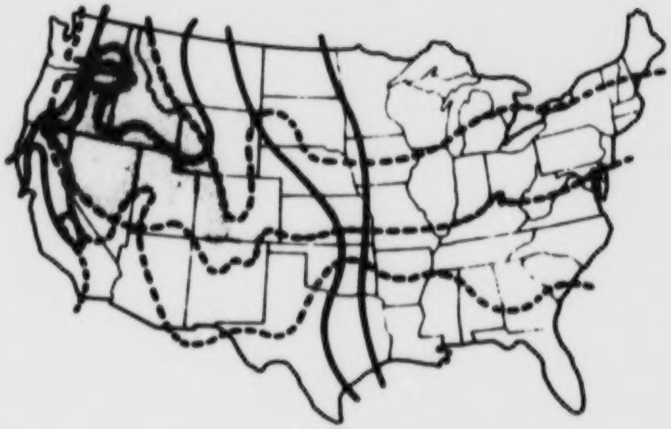


FIGURE II-13. INTERMOUNTAIN REGION

Open Feedlots

With the exception of shade use, windbreaks, or mounds for animal protection, open feedlots--the predominant year-round beef feeding operation in the United States--have little or no environmental controls. Solid and rainfall runoff wastes management system designs should be considered. The accumulation of solid wastes has to be removed from the feedpens periodically, usually at the end of each feeding period. The runoff-carried wastes have to be controlled to prevent pollutant contamination of streams and water supplies. The planning and design for open feedlots should include consideration of feeding and waste handling facilities and resulting operation practices which reduce or eliminate water pollution potentials. These design features can be added to existing lots at a greater expense than if they had been an integral part of the initial construction phase. The design features of open feedlots that affect pollution potentials include extraneous runoff diversion, lot size and surface, lot topography and drainage, collection and retention of manure-contaminated runoff, contaminated runoff storage and disposal, solid waste removal access, solid waste storage and disposal and, in some instances, sun shades and windbreaks. Waste management and handling practices which affect water and air pollution potentials include pen cleaning schedules, retention of partial manure pack in pen, and pen stocking rate.

Open Feedlot Layout. There are as many feedlot layouts as there are sites for their construction. The various designs, however, have similar pollution control designs. An example layout of an open feedlot for a flat or level area is illustrated in Figure II-14 (6). This feedlot is designed for pollution control with recycling of the waste materials through crop production. Other systems may work equally as well. However, this illustration points out some of the main features that would be desirable for pollution control of the runoff-carried waste. The main features on this layout are the drainage paths and treatment and ultimate disposal of the runoff-carried wastes. This feedlot was assumed to be located on

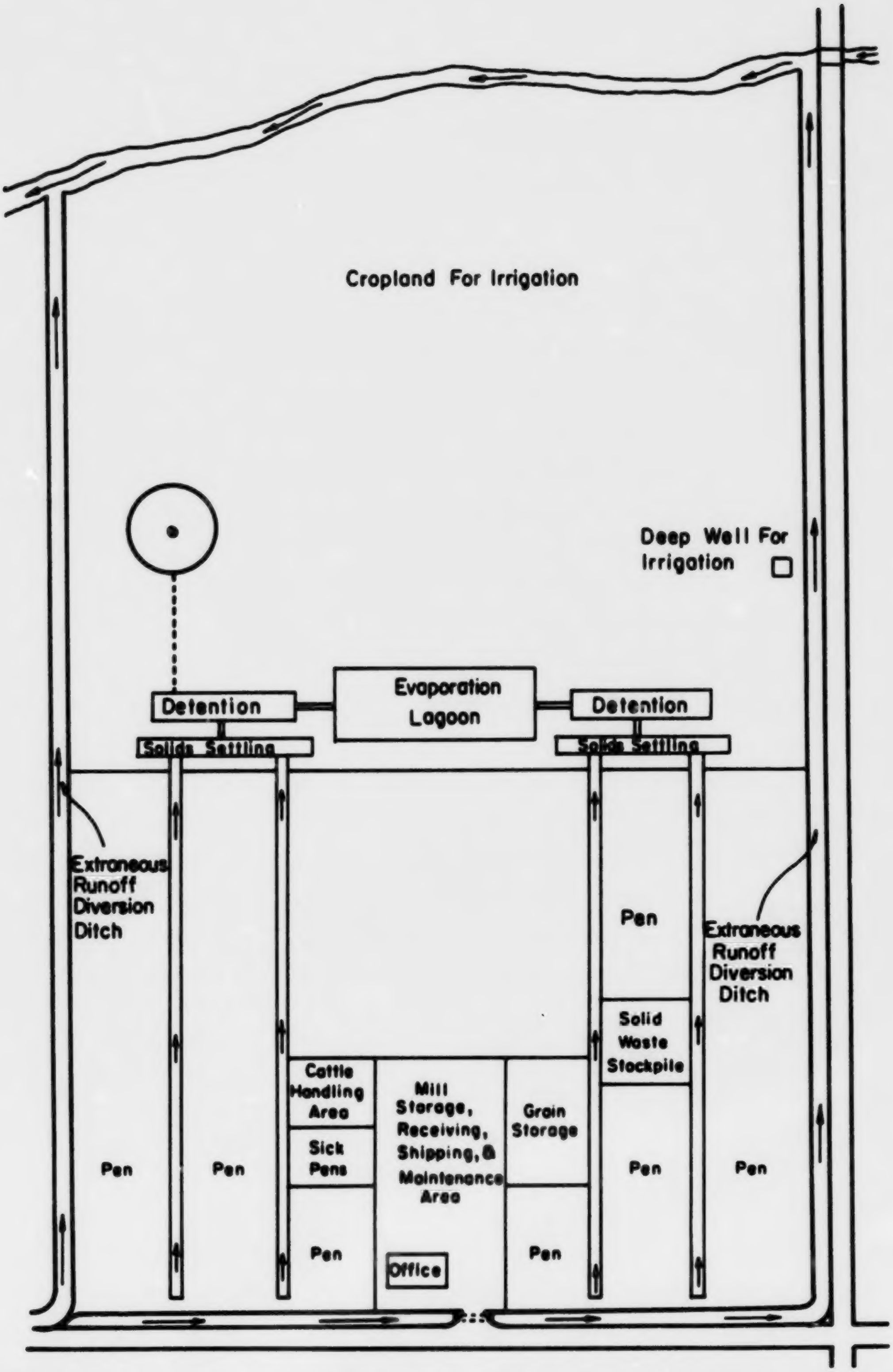

Cropland For Irrigation
Deep Well For Irrigation
Detention
Evaporation Lagoon
Detention
Solids Settling
Solids Settling
Extraneous Runoff Diversion Ditch
Pen
Extraneous Runoff Diversion Ditch
Solid Waste Stockpile
Cattle Handling Area
Mill Storage, Receiving, Shipping, & Maintenance Area
Grain Storage
Sick Pens
Pen
Pen
Pen
Pen
Pen
Pen
Office

FIGURE II-14. SCHEMATIC DIAGRAM OF AN OPEN FEEDLOT WITH RUNOFF CONTROL (6).

a quarter section of land with one-half section available for crop production and irrigation and would be capable of handling between 20,000 and 30,000 head at one time.

An example of a radial layout, similar to a nine acre, 1,000 head layout presently located on a low hill in Kansas, is shown in Figure II-15. Emphasis is placed on runoff control and manure handling features. Pen topography can be shaped to conform to the pen drainage systems illustrated in Figure II-18 (page II-20) cross-section "D" or "E." The primary advantage to this design is the centralization of feed, animal, and wastes handling activities. Automated feed delivery systems may be utilized in this facility; the basic design may be scaled to any desired capacity, depending on the availability of topographically suitable land area, and capacity may be doubled by expanding on the opposite side of the mill and animal handling area.

Figure II-16 is a layout which has been used successfully in many areas when an entire hill or ridge can be utilized. In this case, there is no need for an extraneous runoff diversion ditch. The runoff collection channel encompasses the base of the hill and has settling basins distributed at predetermined intervals. Additional settling basins which drain into the collection channel are, in this layout, located in rills or washes on the hill slope and are totally contained within the collection system. The collection channel drains into a retention pond located along its lower end. The wastes are disposed of on agricultural lands which adjoin the feedlot. These layouts incorporate all of the necessary runoff controls to eliminate the need for waste discharges. This design has been utilized on a lot as large as 35,000 head capacity in a 30-inch rainfall area with a maximum of 300 available acres for runoff waste disposal.

Extraneous Runoff Diversion. Diversion of all outside water is necessary in controlling the runoff from an open feedlot. Construction of runoff diversion ditches around areas where uncontaminated runoff and pollutants converge will control the runoff.

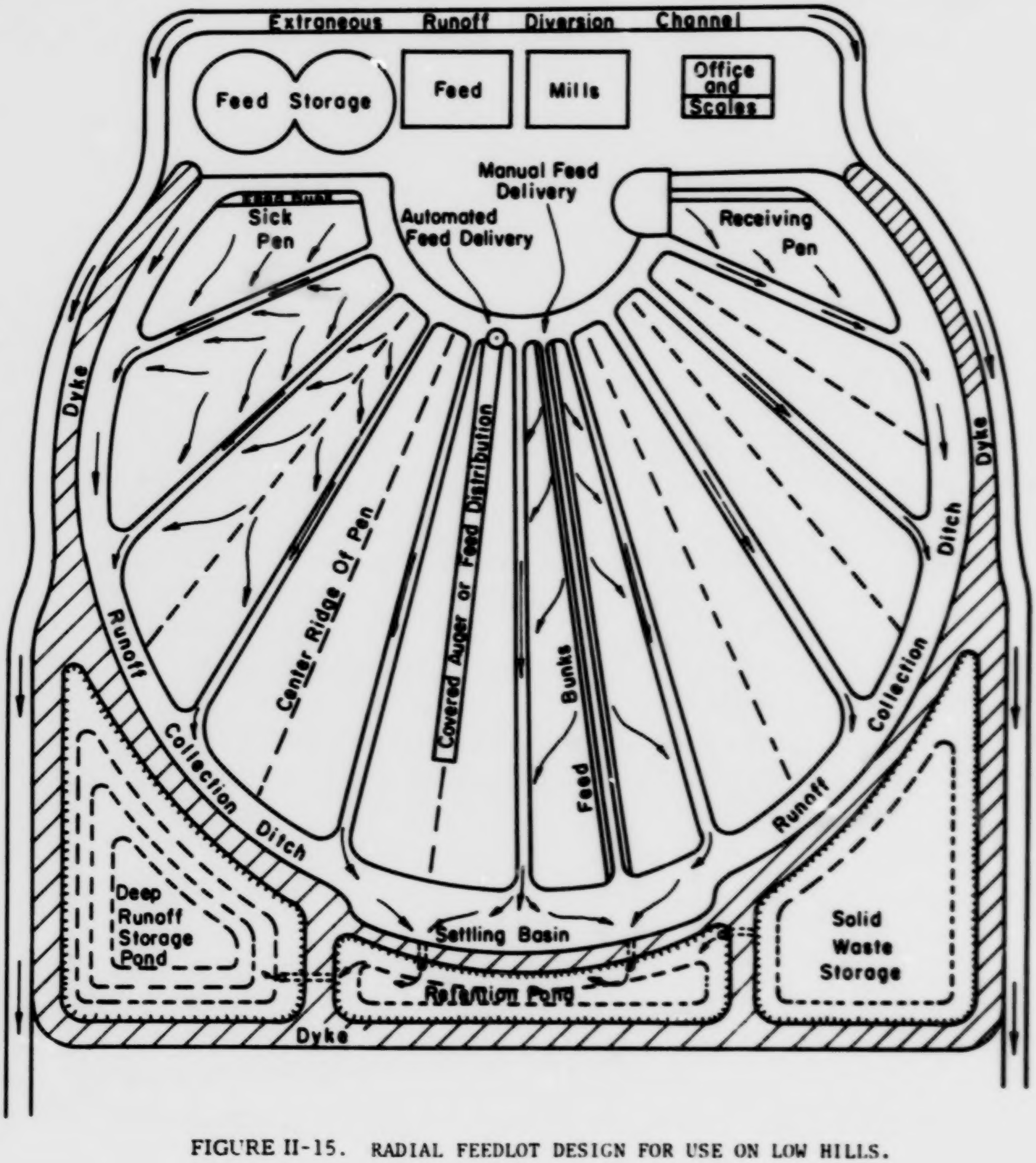

Extraneous Runoff Diversion Channel
Feed Storage
Feed
Mills
Office and Scales
Manual Feed Delivery
Automated Feed Delivery
Sick Pen
Receiving Pen
Dyke
Dyke
Center Ridge Of Pen
Covered Auger or Feed Distribution
Bunks
Feed
Runoff Collection Ditch
Runoff Collection Ditch
Deep Runoff Storage Pond
Settling Basin
Retention Pond
Solid Waste Storage
Dyke

FIGURE II-15. RADIAL FEEDLOT DESIGN FOR USE ON LOW HILLS.

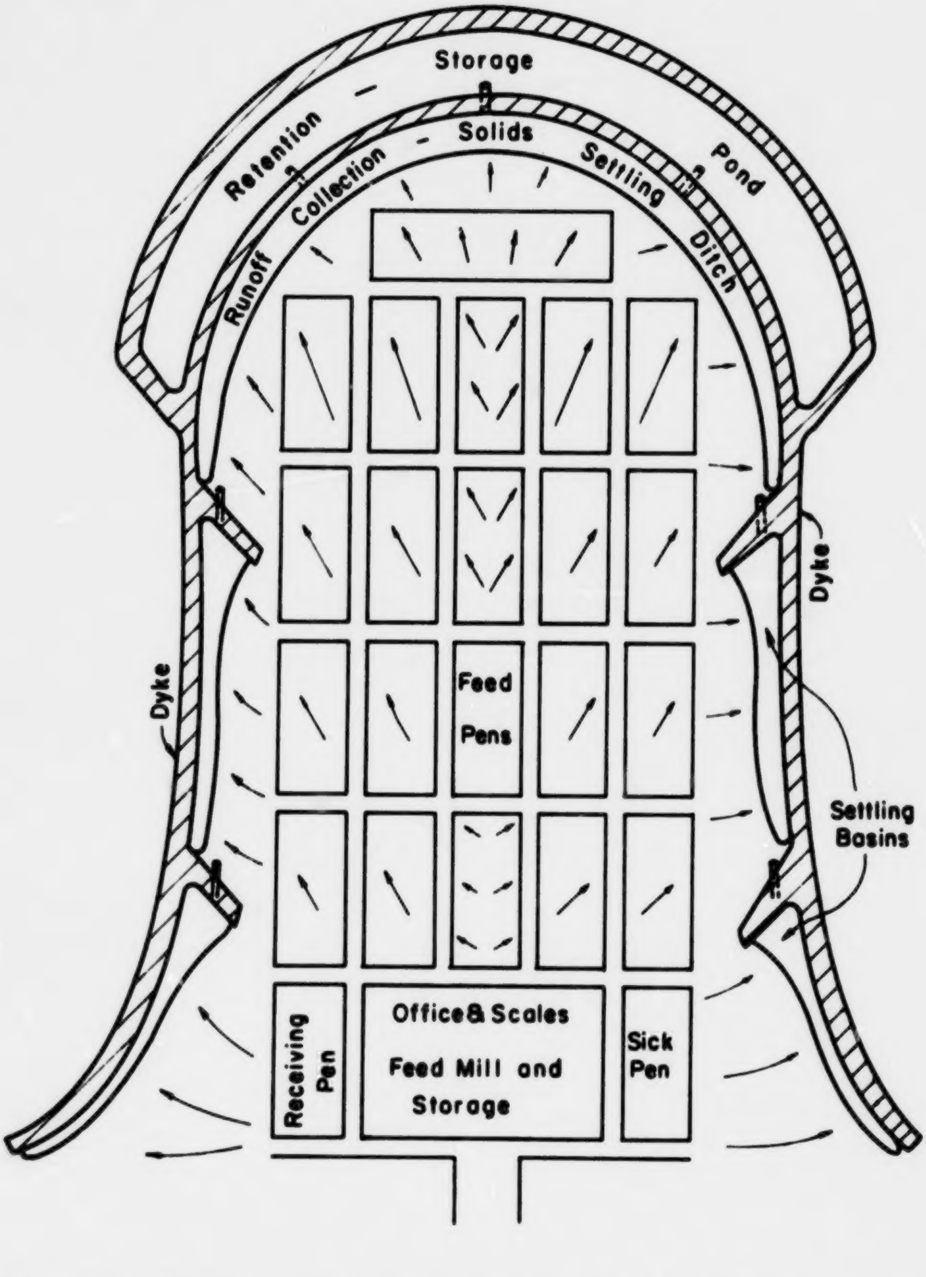

Storage
Retention - Storage - Pond
Runoff Collection - Solids Settling Ditch
Feed Pens
Dyke
Dyke
Settling Basins
Receiving Pen
Office& Scales
Feed Mill and Storage
Sick Pen

FIGURE II-16. SCHEMATIC DIAGRAM OF AN OPEN FEEDLOT WITH TOTAL RUNOFF CONTROL UTILIZING THE CONTOUR OF THE END OF A RIDGE.

The volume of runoff draining from a lot is proportional to the area exposed to rainfall. Thus, the volume of runoff can be computed on a unit of area basis for any given location and set of pen conditions and expanded to fit any size feedlot for that location. The methods of computing runoff volumes will be discussed in Section IV, which deals with the control of runoff wastes.

Pen Surface and Stocking Rates. Pen surfaces can be either unpaved, partially paved, or totally paved. There are advantages and disadvantages associated with each of these pen surfaces depending on local soil, climatic, spatial, and economic conditions.

Unsurfaced dirt lots are less costly to construct and can be used on tight soils in the warmer, drier climates where moisture deficits are greater than rainfall amounts and freezing or winter conditions are not sufficiently severe to create excessively wet or sloppy pen conditions. Dirt-surfaced feed pens should not be constructed on loose or porous soils due to increased groundwater pollution potentials. The removal of solid wastes from dirt-surfaced lots should be performed with care to avoid removal of the lower 3 to 4 inches of compacted manure and soil (Figure II-17). The advantages are threefold. First, groundwater contamination potentials are reduced since the compacted mat provides an impervious anaerobic zone for denitrification. Secondly, once a compacted layer of manure and soil is established, there is less potential for animal traffic to mix soil and manure during periods of wet pen conditions. Thirdly, if this mat is not removed during each cleaning, there is less actual material to be removed from the pens because there is less dirt mixed with the manure, and the added effort of hauling in soil to replace the deficit is eliminated. Dirt-surfaced feedlots require the most land area per animal unit. This is due to pen stocking rates which range between 200 and 400 square feet per animal (Table II-1). The stocking rate should be adjusted to a cattle density which, depending on soil textures and average climatic conditions, will not be conducive to excessively dry (dusty) or wet (sloppy) pen conditions.

FIGURE II-17. THE EROSIONAL FEATURE IN THE CENTER OF THIS LOT EXPOSES THE EDGE OF THE LAYER OF COMPACTED MANURE AND SOIL.

TABLE II-1

SUMMARY OF STOCKING RATES FOR OPEN FEEDLOTS (3) (29) (32)

Lot Surface	Stocking Rate
Unsurfaced	
Dirt, medium textured soil	200-300 ft^2/animal
Dirt, poor drainage on heavy soil	300-400 ft^2/animal
Partially Surfaced	
Concrete slab in front of feed bunk	100-150 ft^2/animal
Surfaced	
Concrete	50-70 ft^2/animal

Partially paved pens usually have a concrete apron, approximately 12 to 20 feet wide and sloped 1 inch per foot, between the feed bunks and the unpaved portion of the lot. If a tractor scraper is to be used for manure removal, this apron can be made wider and the slope reduced to one-half inch per foot. The apron remains relatively dry and stable which encourages animal utilization of the area along the feed bunks during wet periods. Soil type and pen cleaning precautions discussed for dirt lots should be practiced in the dirt-surfaced areas of partially paved lots. Animal densities can be increased to a range from 100 to 150 square feet per animal (Table II-1), thus requiring significantly less land area than all-dirt lots. This results in significantly less area to collect and drain rainfall runoff which, in turn, reduces the amount of contaminated runoff to be stored and disposed. In addition to this pollution control advantage, there may be an economic advantage to this combination of pen surfaces. In many instances, the decreased land area and resulting decrease in required runoff controls more than offset the cost of constructing the aprons in front of the feed bunks.

Totally paved lots have higher construction costs when compared per unit area to dirt lots. The increased stocking capabilities of from 50 to 70 square feet per animal (Table II-1) on paved lots can offset additional costs on a per animal basis especially for smaller feedlots. Considering present trends for pollution control and environmental enhancement, advantages of paved feedlots make them more desirable in many areas of the country. One advantage is the reduction of runoff which drains from paved feedlots on a per animal basis. This is due primarily to the fact that there are greater stocking densities used on paved lots than on unpaved lots, thus less pen area is required. These reduced amounts of runoff require less runoff retention storage and disposal area, simplifying runoff controls and reducing the costs of pollution abatement facilities. Decreased potential for groundwater pollution underneath paved feedlots also makes paved lots desirable. Additionally, paved feedlots offer the possibility of using liquid flushing systems in climatic areas where freezing conditions are encountered only a few days at a time and the possibility of recycling the wastewater for flushing. A continuous daily flow of wastes into a storage/treatment system could be maintained by flushing different pens each day. In some areas, excess water can be utilized for year-round crop or pasture land irrigation. Apparent advantages of this design include inherent runoff control features, manure storage in oxidation ditches or ponds (reducing odor problems), total waste disposal to the land in slurry form (uniquely applicable to irrigation), and a totally automated pollution control system (greatly reducing labor and handling costs).

Pen Drainage. Rainfall runoff draining from feed pen surfaces represents a very noxious waste when allowed to flow uncontrolled into the environment and should be channeled into collection basins for future treatment and/or ultimate disposal. Sufficient land area should be available for waste collection systems, treatment systems, waste disposal areas, and diversion channels. The runoff should be retained on the feedlot property and not permitted to drain to adjoining property. A topographic map is invaluable in planning the drainage system for the feedlot.

There are several topographical designs which can be used for drainage of runoff from unpaved dirt feedlots (Figure II-18) (6). Two of these designs permit drainage to flow through the pens (cross-sections "A" and "B"). The pens in diagram "A" slope from the front and back toward a drain which runs through the middle of the pen. In diagram "B" the pen slopes toward the back with the drainage channel running along the back of the pen. Many feedlots in the past have been constructed with the drainage channel in front of the feed bunks. In this arrangement, the animals must stand in muddy or sloppy areas to feed. It has been shown that the animals have greater feeding efficiency if muddy or sloppy pen conditions can be avoided (5) (17) (24). Sloppy pen conditions can be greatly reduced by sloping the lot surface so that the drainage is channeled down an access alley behind the pen (cross--section "C"). When this method is employed, it is advisable to pave the alley to prevent inaccessibility during and immediately following runoff events (Figure II-19). Cross-sections "D" and "E" are schematic diagrams showing methods of utilizing alleyway channels and "back of the pen" drainage systems in a series. Schematic "D" features automated grain distribution and schematic "E" requires distribution with feed trucks.

Feeding alleys should be oriented to provide the best drainage either at the high side of the lot or up and down the slope. In northerly climates, a north-south or northwest-southeast orientation is preferred because the sun can melt the ice and dry the pavement along both sides of the bank. Roads should be slightly crowned. The lots should be sloped away from buildings and feeding bunks.

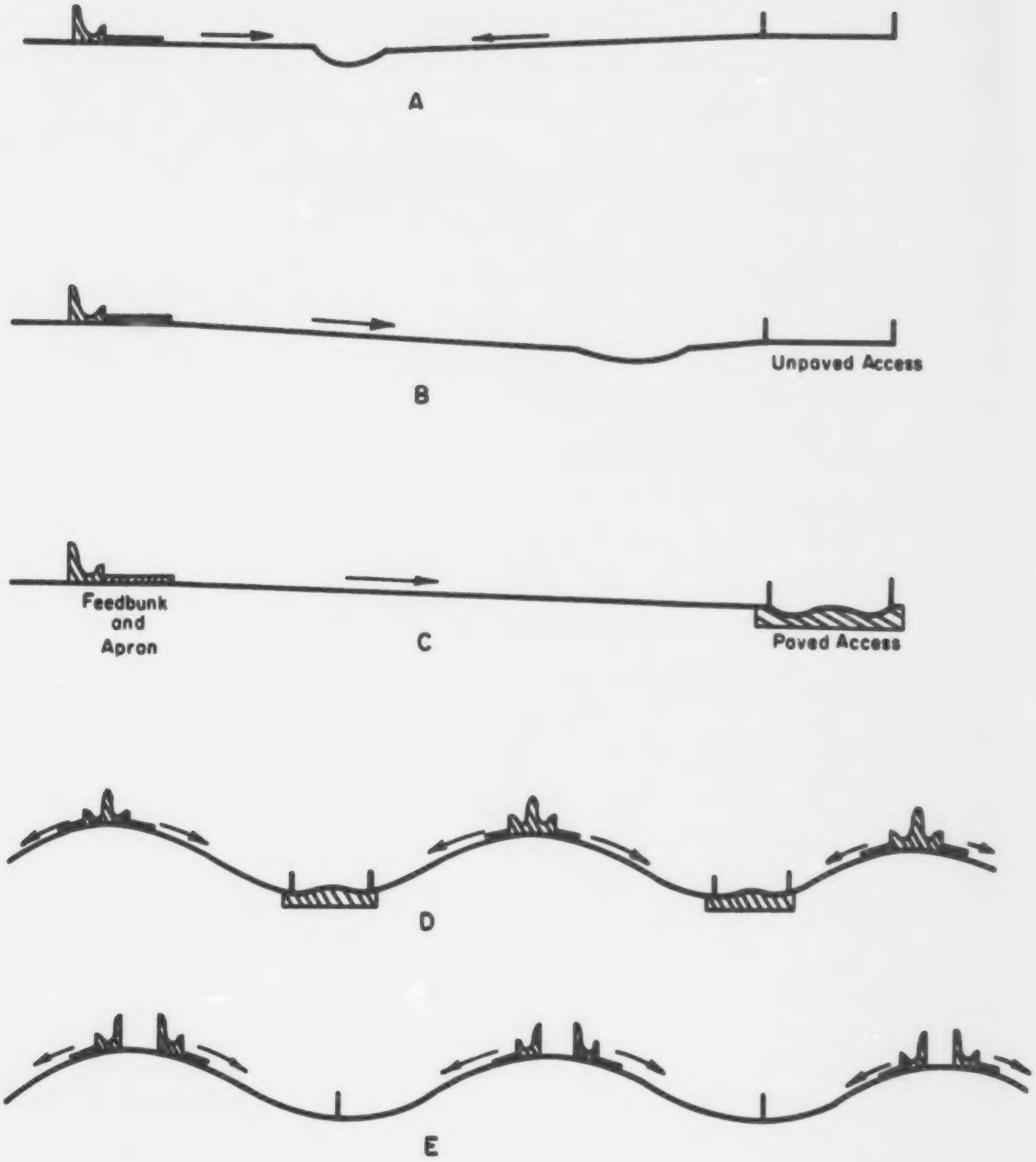

A
Unpaved Access
B
Feedbunk
and
Apron
C
Paved Access
D
E

FIGURE II-18. SCHEMATIC OF PEN DRAINAGE SYSTEMS(6).

FIGURE II-19. IMPASSIBILITY COULD HAVE BEEN AVOIDED BY PAVING AND CROWNING THIS ALLEYWAY.

Slope of the Feed Pens. The slope of unpaved feed pens should be 3 to 6 percent (6). A slope of less than 3 percent will result in sloppy pen conditions due to improper drainage and a slope of 6 percent can cause problems controlling runoff and the transport of solids in the runoff. When through pen drainage channels cross the direction of the pen slope, the channel slope from one pen to the next should be great enough to insure adequate drainage but not greater than the pen slope (Figure II-20). If the drainage is channeled down alleyways or ditches outside the pen, the alley or ditch slope should be slightly greater than the pen slope. This increases the rate of flow, in turn, reducing sedimentation in the primary drainage channels.

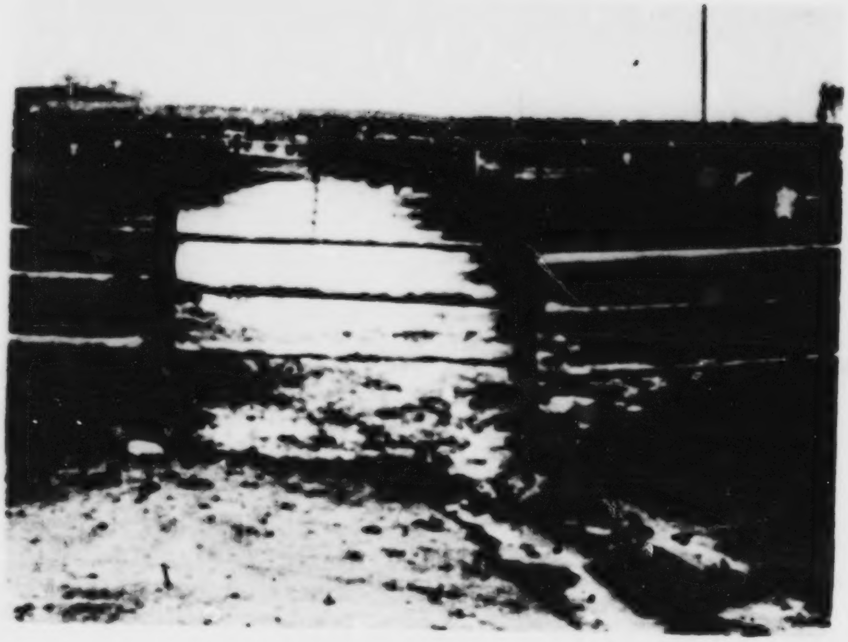


FIGURE II-20. THE SLOPE ON THIS INTRA-PEN DRAINAGE CHANNEL IS NOT GREAT ENOUGH TO ACHIEVE PROPER DRAINAGE.

A pen slope of 2 to 4 percent in paved feedlots, in addition to insuring adequate drainage conditions, is desirable to reduce the amount of solids transported from the pen area in rainfall runoff. In paved lots with flush removal, a pen slope of 7 percent is desirable to achieve adequate solids removal. Runoff waters are generally channeled from the pens in gutters which are constructed along the downslope edge of paved feed pens.

Runoff Collection and Retention. Runoff collection and retention facilities are comprised of a collection ditch designed to interrupt the flow from the pen drainage system and a collection pond designed to temporarily hold the runoff until it can be treated or disposed of. The collection pond is for short-term retention. Many states have set time limits, such as 7 or 10 days, for runoff retention in these ponds. These limits are imposed primarily to maintain collection capacity for additional rainfall runoff in the ponds. A storage pond may also be constructed if long-term storage is needed to facilitate disposal. Runoff then can be pumped from the collection system into the storage pond.

The concentration of oxygen demanding pollutants and total solids in runoff is reduced as much as 90 percent by removal of settleable solids and by dilution from rainfall which falls directly into the retention and/or storage ponds (22). Retarding runoff velocities in the collection ditch and adding a shallow settling basin upstream from the collection pond will facilitate the removal of settleable solids. Collection ditches having a slope 1 to 3 percent less than that of the pen drainage channels will retard runoff velocities sufficiently to settle out a large fraction of the solids. Wide, shallow collection ditches have a large surface area for evaporation; these will dry sufficiently between runoff events to permit solids removal in conjunction with routine pen cleaning (Figure II-21). To obviate sloppy pen conditions, collection ditches which transect pens should not be used for settling solids. Settling basin, retention pond, and storage pond designs are discussed in detail in Section IV.

Environmental Modifications. Little can be done to modify the animals' environment in open feedlots as compared to open confinement shelters. Three major modifications that can be undertaken in open feedlots are: (a) the construction of shades to reduce the amount of solar radiation on the animals and the amount of rainfall that might otherwise fall into the feed bunk, (b) the use of windbreaks to provide modification of the animals' environment, particularly for wintertime conditions (Figure II-22) (some recommendations for windbreaks are given in the Midwest Plan Service Booklet on Beef Housing (3)), and (c) the preparation of

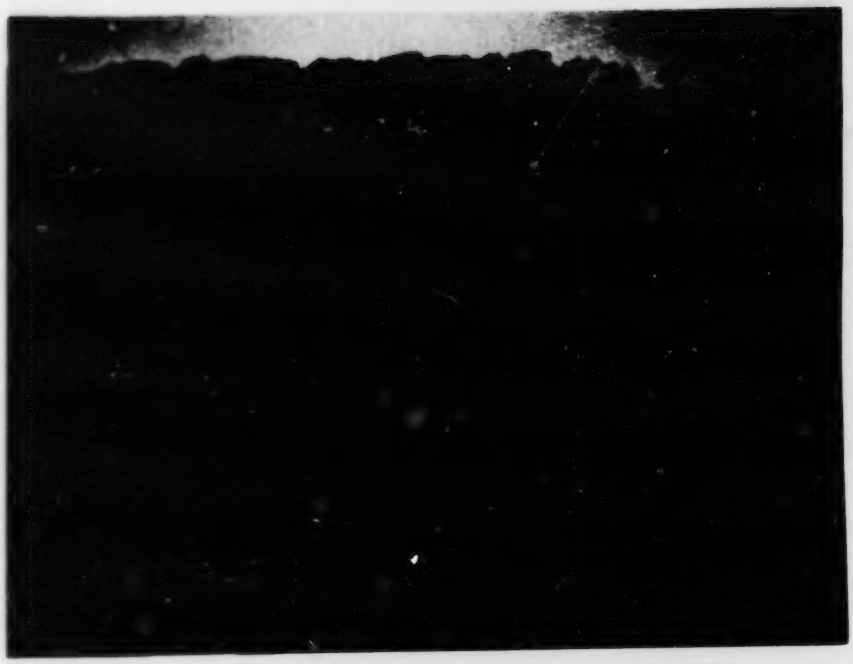


FIGURE II-21. THE PORTION OF THIS COLLECTION DITCH LOCATED ABOVE THE CULVERT DOUBLES AS A SETTLING BASIN.

mounds in the feedlots to provide higher ground for dryness during wet weather, air movement in warm weather, and some shelter from the wind during winter weather.

Open Confinement Feedlots.

Climatic conditions in different geographical areas of the country necessitate diversity of feedlot designs. The advantages of open feedlots in the drier portions of the mild and warm climates have been discussed. Total confinement buildings with inside environmental control, necessary for optimum animal performance and pollution control in areas of extreme temperature and rainfall, will be discussed in the following section. Open confinement feedlots are essentially a combination of design principles and waste management alternatives utilized in open feedlots and total confinement buildings.

FIGURE II-22. THESE LOMBARDY POPLARS WERE PLANTED TO PROVIDE SOME ANIMAL PROTECTION FROM THE WIND.

In an open confinement facility, the animals are free to move about in an outside lot and seek protective shelter in a shed or building when desired. These facilities can be designed for specific geographical and/or climatic areas where open feedlots do not provide sufficient environmental pollution controls or animal protection, but where total confinement facilities exceed the design criteria for economic production. Open confinement feedlot designs range from dirt lots with loafing sheds to totally covered buildings which are enclosed on three sides and open into an open lot area on the fourth side. Some of these covered buildings may have slotted floors over manure collection pits or oxidation ditches.

Open Confinement Feedlot Design. Figures II-23 and II-24 depict two variations of open confinement facilities. Variations of the open confinement facility with loafing sheds depicted in Figure II-23 can be used to provide cattle with some protection from solar radiation in warmer, less humid areas. Feeding is generally done with an outside feed bunk located either in the center of the lot, where mechanical feeders would be used, or along the outside of the pens where feed trucks or wagons would be used. The building floors and lots may be paved or unpaved. Variations of the basic facility design illustrated in Figure II-24 are usually used in the cooler, more humid areas where greater animal protection is needed and the reduction of runoff from the feedlot surface is desirable. This type of facility is used in areas where total confinement of cattle is necessary during winter months. The animals are allowed free passage between the open lots and the buildings during the milder portion of the year. As noted above, open confinement feedlots are essentially a combination of design principles and waste management alternatives utilized in open feedlots and total confinement buildings. Design requirements for this open air portion of the open confinement feedlot (extraneous runoff diversion; pen surface, drainage, and slope; and runoff collection and retention) may be ascertained by studying the previous section on open feedlots and proceeding as though planning an open feedlot. Animal densities can be increased from those used for open feedlots to 30 square feet per animal. The overall design can then be completed by selecting the desired design alternatives for the covered portion of the facility. These are discussed in detail in the following section on total confinement buildings. Alternatives which should be considered for roofed areas include feed bunk location, flooring types, and waste management systems.

Total Confinement Buildings

Beef feeding in total confinement buildings has become increasingly profitable in some areas of the United States. The trend toward confinement beef feeding buildings has been primarily in the upper Midwest

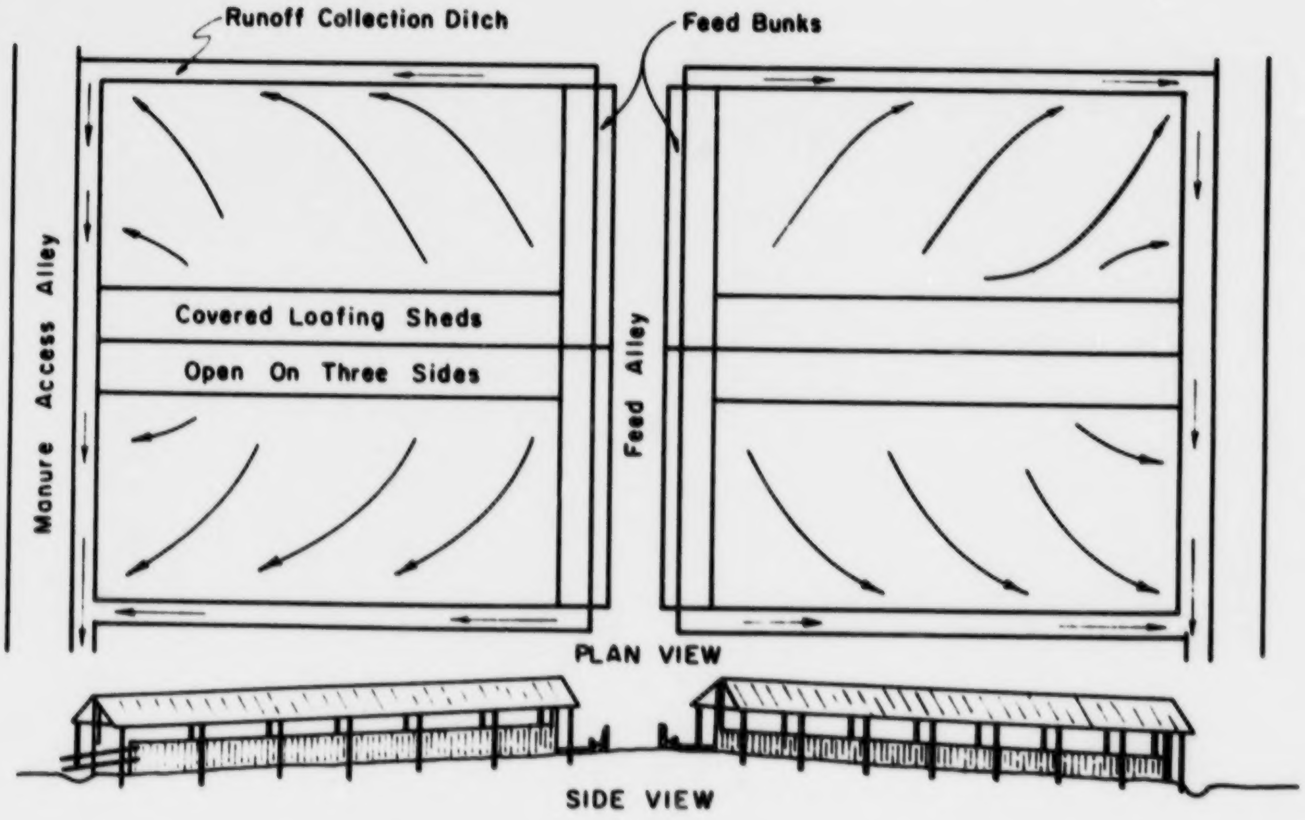

Runoff Collection Ditch
Feed Bunks
Manure Access Alley
Covered Loafing Sheds
Open On Three Sides
Feed Alley
PLAN VIEW
SIDE VIEW

FIGURE II-23. OPEN CONFINEMENT FEEDPENS WITH A LOAFING SHED AND A RUNOFF DRAINAGE SYSTEM.

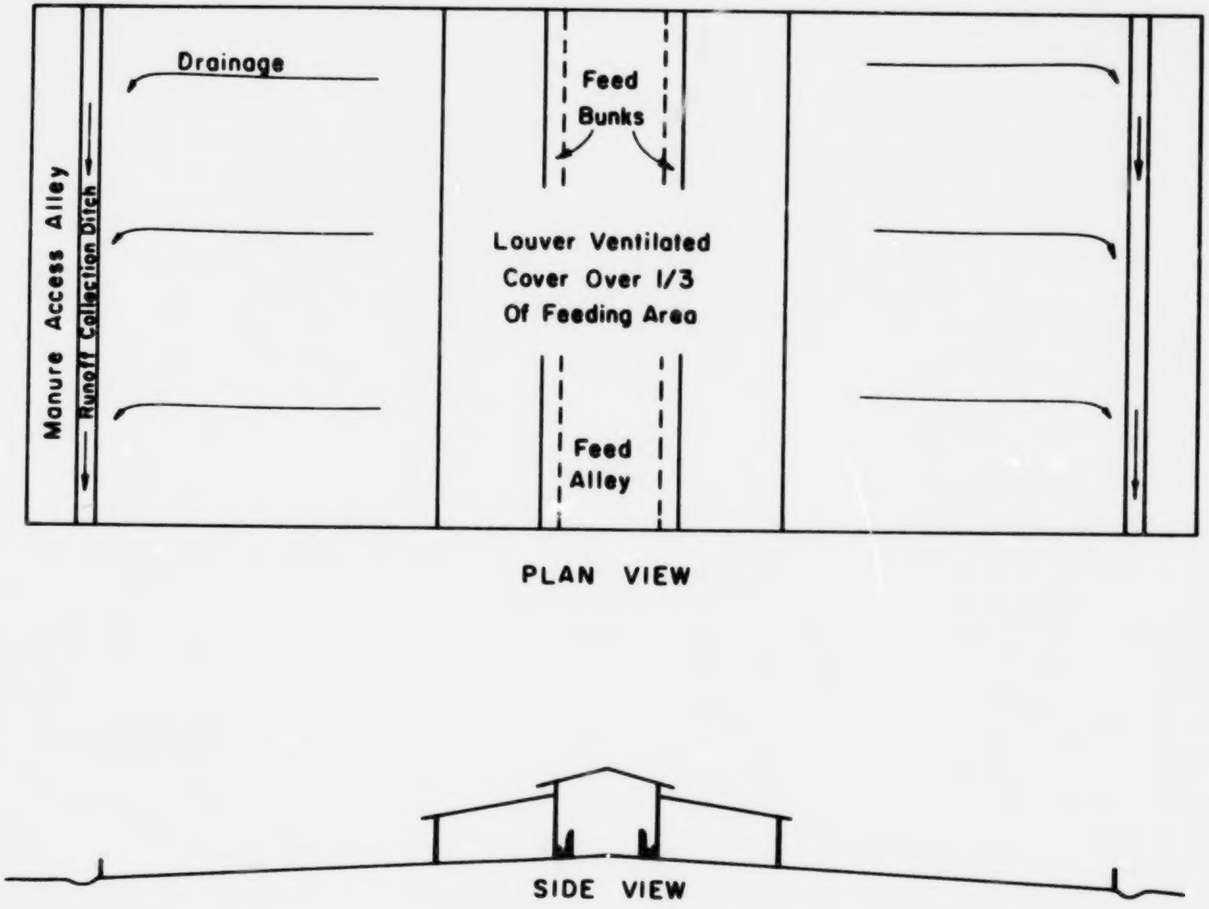
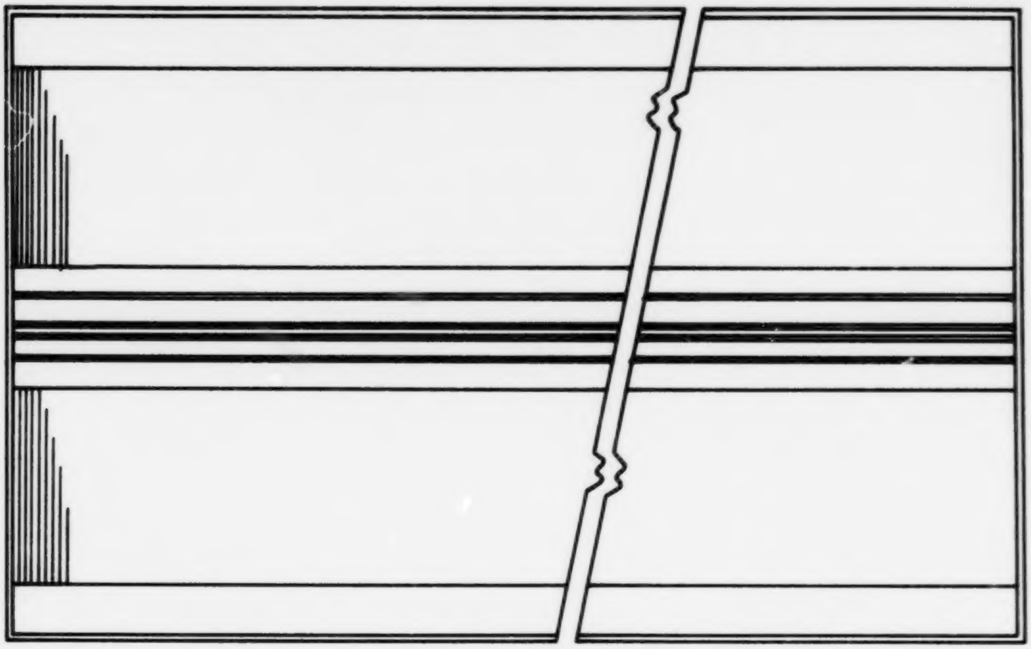

Manure Access Alley
Runoff Collection Ditch
Drainage
Feed
Bunks
Louver Ventilated
Cover Over 1/3
Of Feeding Area
Feed
Alley
PLAN VIEW
SIDE VIEW

FIGURE II-24. OPEN CONFINEMENT FEEDPENS WITH COVER OVER 1/3 OF THE FEEDPEN AREA AND A RUNOFF DRAINAGE SYSTEM.

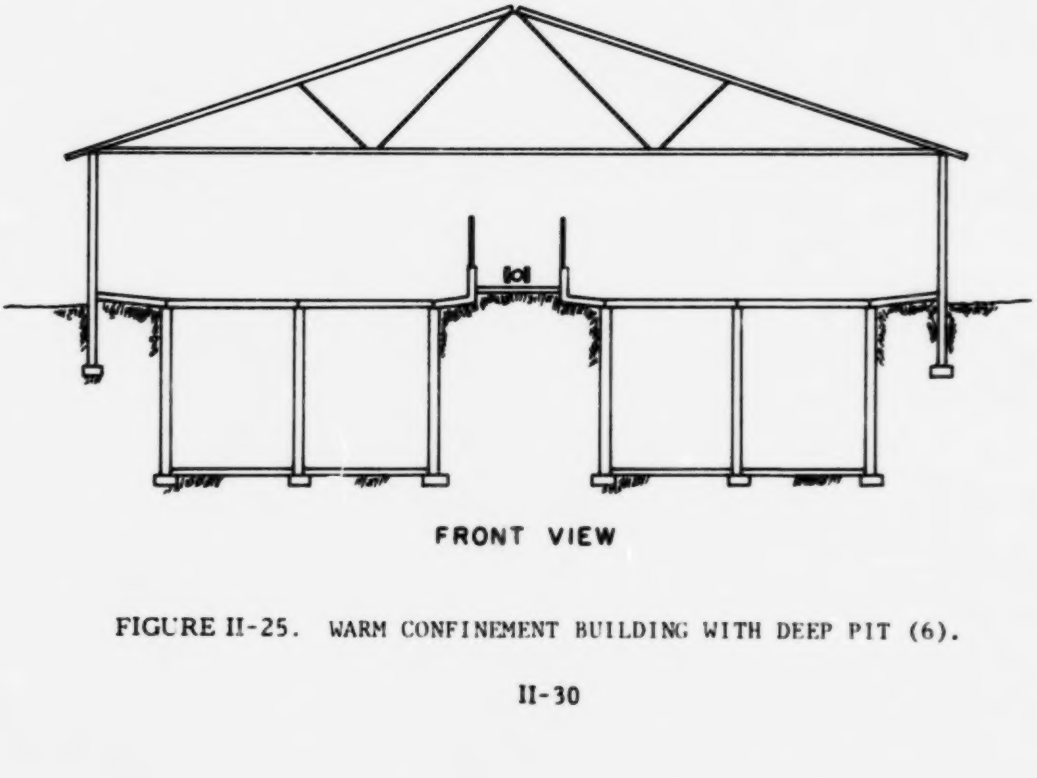
where the animals can be housed to protect them from the severe winter and muddy spring weather conditions that exist in open feedlots. Beef confinement buildings are located in the Northern Great Plains and Corn Belt states in areas where family farms predominate. Thus, the capacities of the facilities are often less than 1,000 head with most facilities housing between 200 and 500 animals. There are a few facilities with a 10,000 to 20,000 head capacity.

Feeding in outside lots in regions of extreme temperatures and/or high rainfall and humidity seriously affects the animals' performance and health. Additionally, pollution controls for facilities with outside lots begin to border on the limits of economic feasibility in those areas of extreme cold and/or moisture. These conditions offset the economics of total confinement of the animals. The control of animal environment can range from removable side curtains or closures in warm, humid climates to insulated buildings with artificial heat or cooling in extreme temperature areas.

Types of Confinement Buildings. There are several main frame and building styles for confinement buildings. Pole type buildings with interior poles have been used, particularly with solid floors. However, clear span buildings are most prevalent because of easier access for cleaning with mechanical equipment. Most of the slotted floor buildings have clear spans over the slotted floor areas. These spans may range from 24 to 60 feet. Roof shapes include gable, quonset, or half-mansard styles. The feed bunk location may be down the center of the building, along the outside walls, or outside the pens with a drive for feed trucks. For the smaller, totally confined buildings, mechanical feeders are usually used. Confinement buildings are the most effective during periods of inclement weather but require adequate ventilation for animal comfort during summer months. Figures II-25 through II-29 are illustrations of typical building designs observed by Butchbaker et al.(6) in 1970.

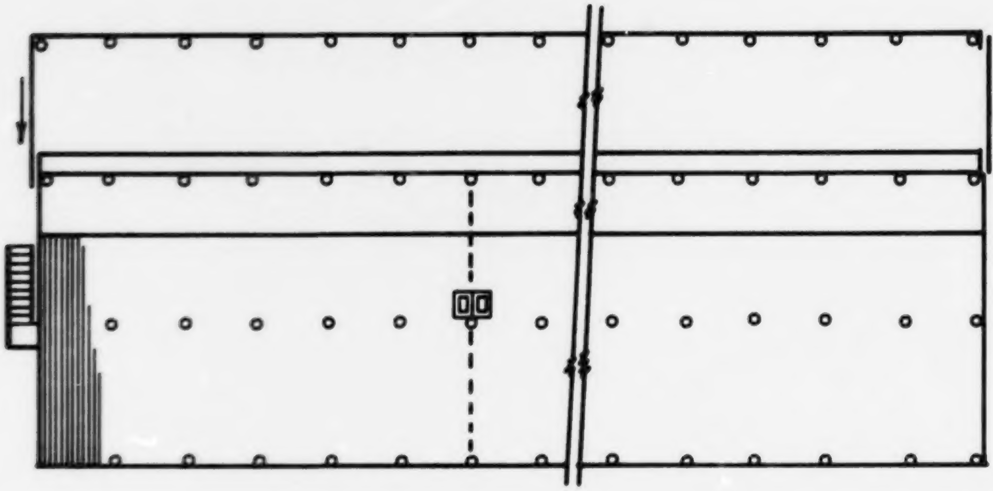


PLAN VIEW

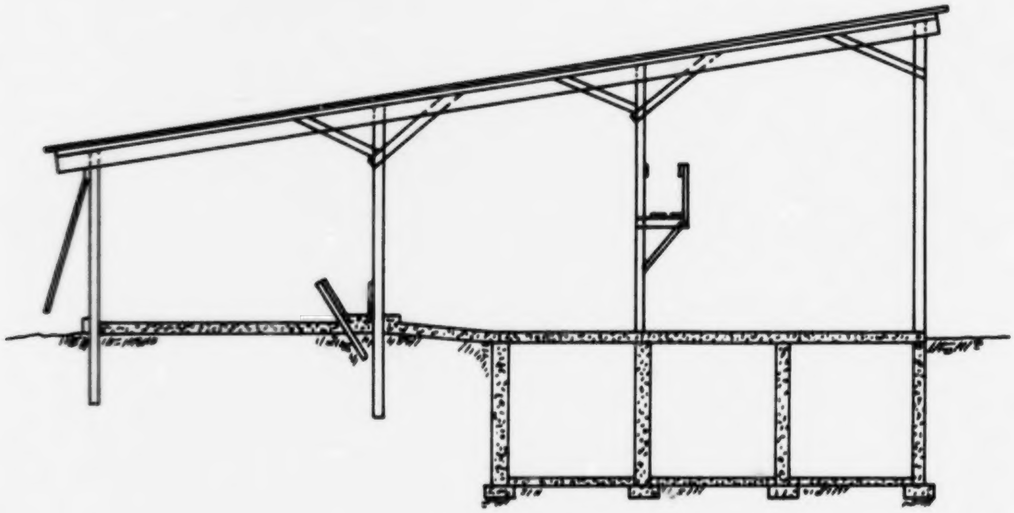


FRONT VIEW

FIGURE II-25. WARM CONFINEMENT BUILDING WITH DEEP PIT (6).

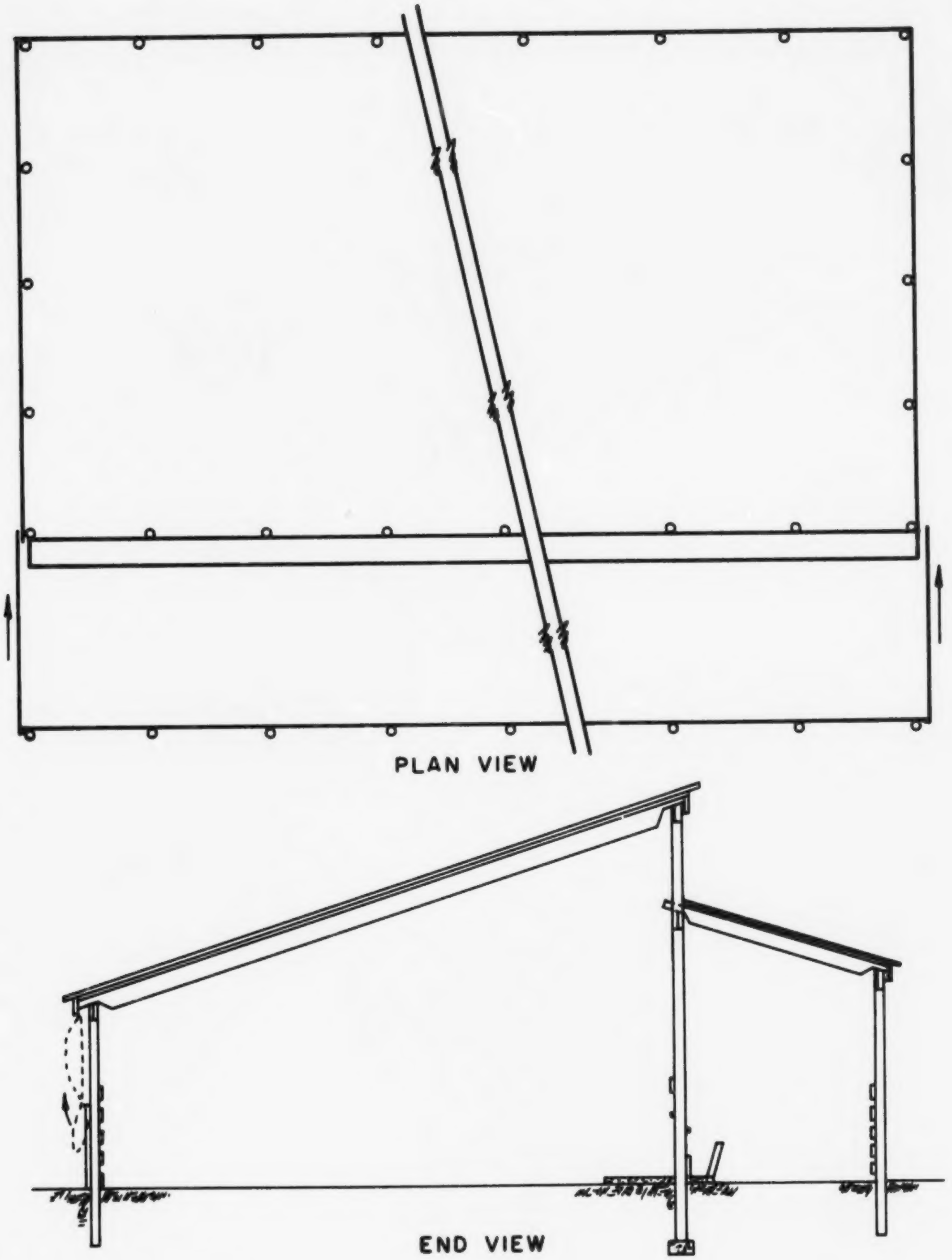


PLAN VIEW



END VIEW

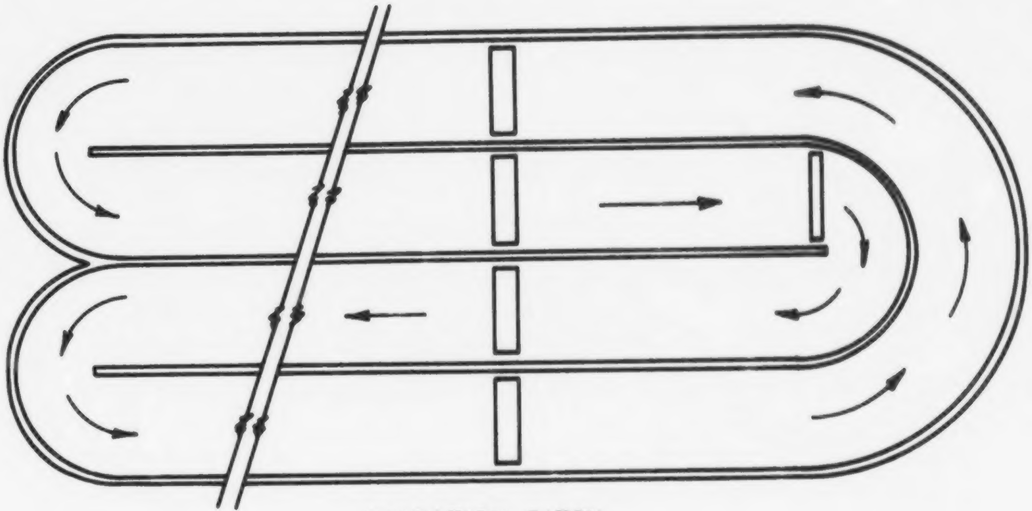
FIGURE II-26. COLD CONFINEMENT BUILDING WITH DEEP PIT (6).



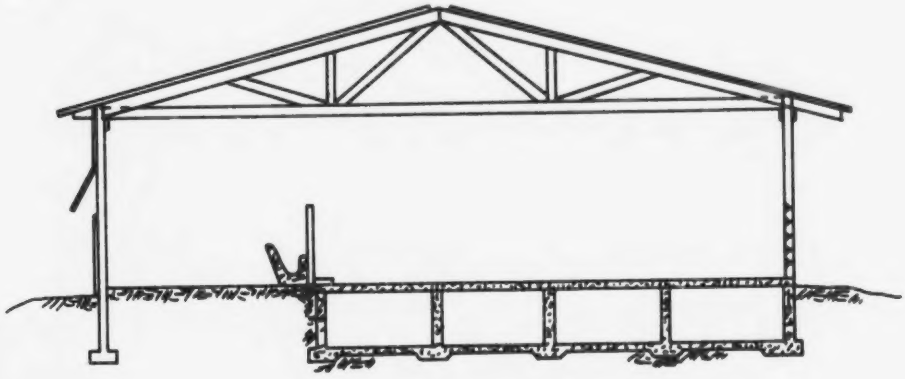
PLAN VIEW

END VIEW

FIGURE II-27. COLD CONFINEMENT BUILDING WITH DIRT FLOOR AND CANVAS SIDE CURTAINS (6).

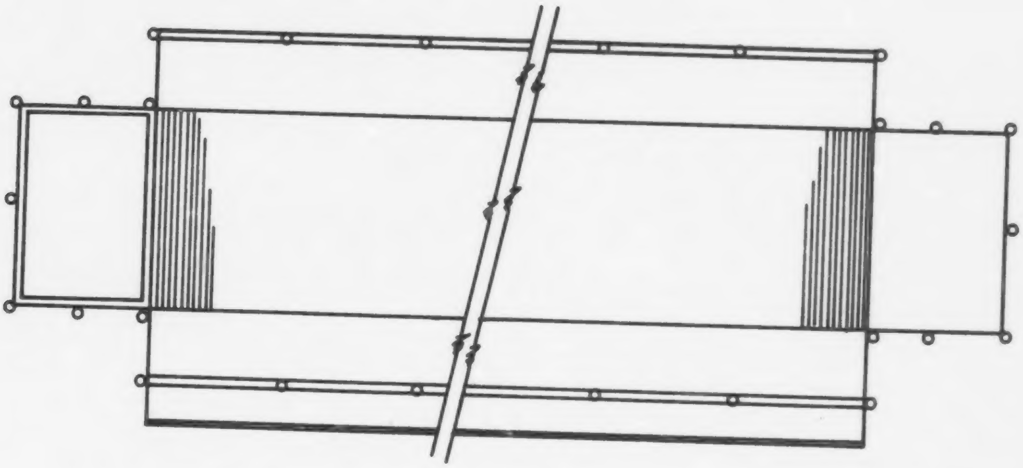


OXIDATION DITCH

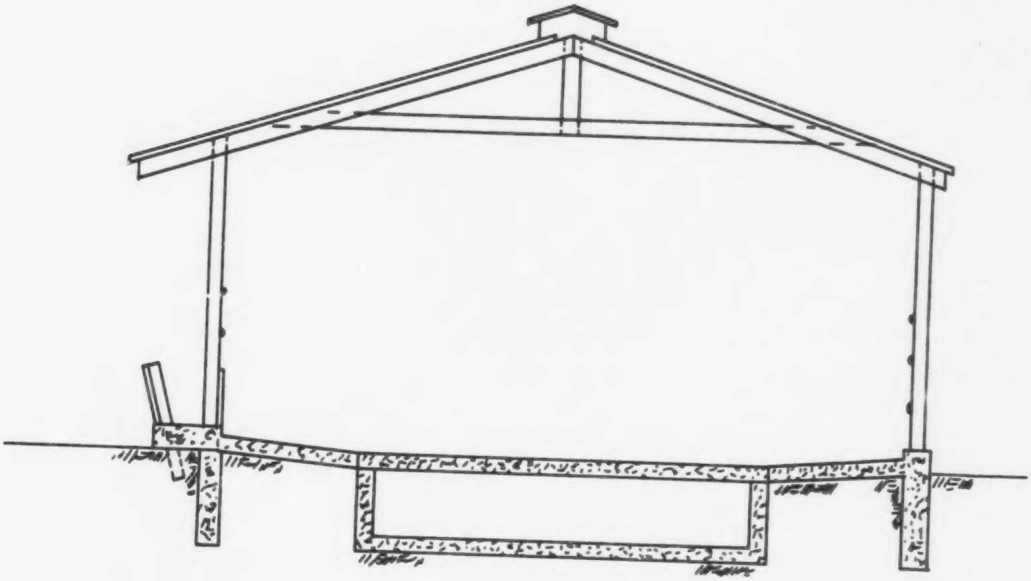


END VIEW

FIGURE II-28. COLD CONFINEMENT BUILDING WITH SHALLOW PIT FOR OXIDATION DITCH (6).



PLAN VIEW



END VIEW

FIGURE II-29. COLD CONFINEMENT BUILDING WITH SHALLOW PIT FOR CABLE SCRAPER.

Basic Classifications of Confinement Buildings. Figure II-30 classifies various confinement buildings. A total confinement building may be basically either a cold or warm confinement facility.

Cold confinement buildings usually have open fronts facing south or east. The barns are usually enclosed on the north and west sides during the winter; however, during the summer, removable panels allow free airflow and the roof provides protection from intense solar radiation. For winter operation, the panels are put in place to provide a dry, relatively draft-free environment. Unlike open confinement feedlots, there are no unroofed pen areas. During winter months, temperatures within the building average 10 to 20 degrees higher than outside air temperatures as a result of solar radiation conducted through the roof, heat radiating from the animals, and heat produced by decomposition of manure and bedding.

Warm confinement buildings are well insulated and mechanically ventilated. The amount of insulation varies with the climatic areas; however, 2 to 3 inches of standard insulation (k = .27 to .30) $\frac{\text{BTU}}{\text{ft.-hr.}}$ are used in the side walls and 4 to 6 inches in the ceiling. Exhaust fans are specifically located to remove the warm moist air during the winter months. Although some buildings have fans installed on the sidewalls, many fans are placed so that air is drawn down through the slots to remove any noxious gases evolving from the manure storage pit underneath the slotted floor. Inlet areas are also provided at strategic locations to insure uniform distribution of the air. In extremely cold climates where subzero temperatures occur, cold air may cause fogging and condensation near the inlets. Some barns have heat exchangers which utilize outgoing air to partially warm incoming air or heaters to provide additional control of the air temperature and manure moisture.

During the summer months, most of the warm confinement barns have extremely high airflow rates that cause evaporation of moisture within

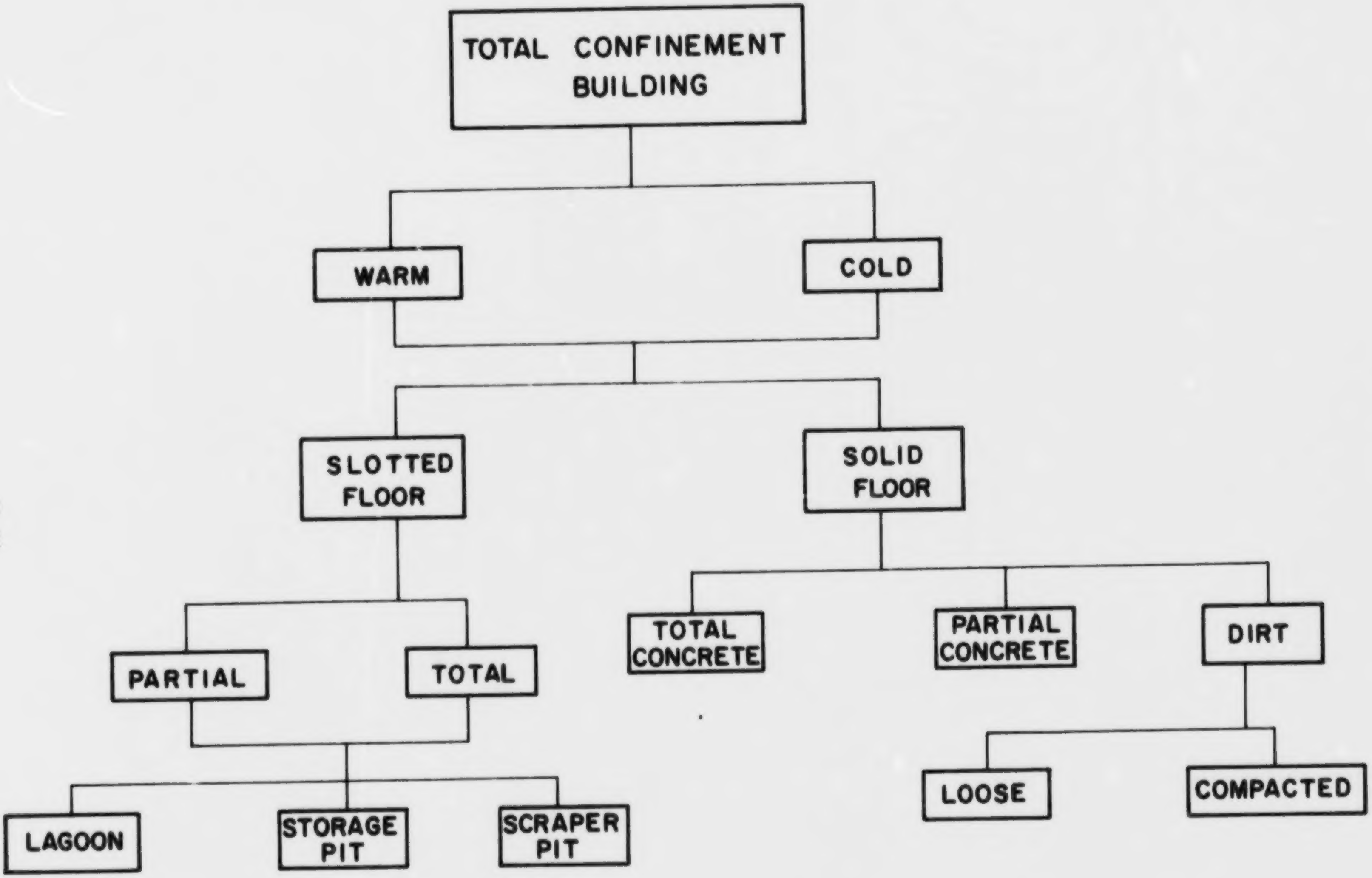

TOTAL CONFINEMENT BUILDING
WARM
COLD
SLOTTED FLOOR
SOLID FLOOR
PARTIAL
TOTAL
TOTAL CONCRETE
PARTIAL CONCRETE
DIRT
LAGOON
STORAGE PIT
SCRAPER PIT
LOOSE
COMPACTED

FIGURE II-30. TOTAL CONFINEMENT BUILDING CLASSIFICATION AND FLOORING TYPES.

the building, thus taking sensible heat from the air for the latent heat of evaporation. Therefore, most totally insulated buildings have an inside temperature lower than the outside temperature during the warm part of the day. The effects of solar radiation are reduced by the shading and time lag between the maximum solar radiation and the transmission of the thermal energy to the interior of the building. Evaporative coolers or mechanical refrigeration systems can be used for cooling the incoming air during the summer months.

Pen Stocking Rates. Pen stocking rate as it affects spatial requirements is the major difference between confinement building design and open feedlot design. Square footage requirements of cattle can be expressed as a function of body weight. Space requirements for confinement buildings are approximately 2 square feet of space per 100 pounds of body weight for wintertime conditions and up to 3 square feet per 100 pounds of body weight for hot weather conditions. Thus, floor space for confinement feeding facilities, particularly on slotted floors, is approximately 18 to 25 square feet per head. Again, feed bunk space depends on the frequency of feeding. With three or more feedings per day, feed bunk space could be approximately 6 inches per head.

Flooring Types. In total confinement buildings, there is a choice between a solid or slotted floor (Figure II-30, page II-36). A solid floor may be entirely dirt, entirely paved, or a combination of the two. Partially dirt floors may permit some moisture to percolate through the soil. As with open feedlots, some facilities have a concrete apron located beside the feed bunk with the remainder of the floor being dirt. Other facilities have the entire building floor paved. A slotted floor may be either totally or partially slotted. A partially slotted floor has concrete, steel, or wood slats 3 inches wide, spaced 1½ inches apart, spanning the distance between concrete aprons located along the outside wall and the feed bunk. These aprons slope approximately 1 inch per foot toward the slotted floor area. The waste material is worked down the sloped aprons and through the spaces between the slats by the cattle's hoofs and drops into a pit underneath the slots. Some facilities lack one or both aprons, thus the entire floor is slotted.

Waste Management Systems. There are essentially three different systems for removing the waste material. The first is a solid handling system similar to the solid wastes removal systems for the open confinement feedlots. The second is a wet removal system where both the combined feces and urine form the slurry without the addition of water. The third is a water flush system used to remove and transport the waste material from solid concrete floors and shallow pits below slotted floors to storage.

Solid wastes handling steps involve scraping the manure into a pile or loading it directly into a spreader. The most common method is to use a front-end loader with a tractor dumping the material into a spreader pulled by a tractor. Small commercial loaders can also be used in place of tractor mounted front-end loaders. Solids handling and disposal alternatives are discussed in detail in Section V.

Slurry handling systems are used primarily where slotted floor systems have been installed. The volume of the pit underneath the slotted floors depends primarily upon the frequency of removal of the slurry, number of animals, and the floor structure. The two major types of storage pits are (a) a deep storage pit for storing the slurry several months at a time and (b) a shallow pit for storage of the material for only a few days. The latter system is used if a cable scraper removes the slurry wastes on a daily basis. In most cases, attempts are made to prevent extra water from entering the pit.

Deep pits for confinement buildings are usually 8 to 10 feet in depth underneath a totally or a partially slotted floor. The pits fill at the rate of about 1 foot per month for a totally slotted floor. For beef animals, it can be assumed that approximately 1 cubic foot of manure per day is produced at a density of about 60 pounds per cubic foot, wet weight, and a moisture content of 85 percent for a 1,000 pound animal (14). Evaporation will reduce the volumes in the manure pit. The volume should be sufficient for detention of wastes between removals, which are generally two times per year, March-April and October-November, coinciding with the corn growing seasons in the Midwest.

Cable scraper or hydraulic flushing methods are used for manure removal in shallow pits from 1 to 2 feet deep underneath slotted floors. The cable scrapers, similar to those used in poultry installations, move the material towards one end of the building into a cross conveyor or pit. From a pit at the end of the building or a central collecting pit for several buildings, the slurry can be pumped into tank wagons for field application or to other temporary storage locations. Because the cable scrapers are operated daily, there is limited buildup of manure and there appears to be fewer odor and fly problems than with the solid handling or deep pit storage systems for confinement buildings. Slurry removal, handling, and disposal alternatives from deep and shallow pits are discussed in detail in Section VI.

Hydraulic flushing systems can be used instead of mechanical scrapers. Some systems utilize recycled water from a lagoon or a solids separation system. Pratt et al. (28) reported on a water reuse system for flushing down the floors of an experimental beef confinement building. Recycled liquids were effectively used to flush the waste material; however, the water was dark in color and odors were prevalent. The investigators concluded that recycled water needed additional fresh water to control odors and to replace losses due to evaporation. Due to a tendency to freeze in open buildings, liquid flush systems for beef confinement buildings with solid floors are not in prevalent use in the Upper Midwest or the colder climates. During cool weather, livestock may remain damp, particularly in solid floor systems. Waste handling and disposal alternatives for hydraulic flushing systems are discussed in detail in Section VI.

Ventilation. Environmental control to modify the outside extremes such as air temperature, humidity, wind, and solar radiation, is a major consideration for total confinement feeding facilities. Adequate ventilation of the manure storage pit is particularly important. Noxious gases are prevalent when the slurry is removed from pits and extreme care should be exercised to control odors and prevent loss of life. The primary noxious gases are ammonia, carbon dioxide, methane, and hydrogen sulfide. Animals can be removed from the facility during times when the manure is removed.

The National Safety Council recommends the following precautions for work around manure pits.

1. Never work alone.
2. Use a lifeline and make sure there is power enough to lift a victim clear of the tank.
3. If you must go inside a tank, ventilate the tank before entering it and during the work.
4. Test for combustible gases and oxygen level with an appropriate testing device.
5. If in doubt, use self-contained air breathing apparatus.

Advantages of Confinement Buildings. The main advantages of confinement cattle feeding buildings are (6):

1. providing the initial collection step for a waste management system,
2. less labor in feeding and manure disposal,
3. no bedding if slotted floor systems are used,
4. better feeding performance as indicated by generally higher rates of gain and better feed efficiencies,
5. protection from severe weather and more comfortable animals as evidenced by quieter and more docile cattle in confinement buildings,

6. cleaner and healthier cattle as evidenced by fewer parasites and insect problems and freedom from hoof rot and other diseases caused by muddy feedlots, if housed on a slotted floor, and
7. elimination of the need for pasture and a large outside lot requiring additional land.

Bates et al. (2) and Smith et al. (3) reported on the influence of housing on the performance of beef cattle housed in five different structures (Table II-2). They found that warm housing produced the highest daily gains with the lowest amount of feed per pound of gain. The greatest relative advantage of shelter occurred during the period from February 17 to May 11 in southwestern Minnesota. The performance and carcass characteristics were not greatly affected by different animal densities in any of the units. The housing units consisted of a slotted floor cold confinement building, a manure scrape barn (solid dirt floor with the manure pack with an outside lot for feeding), outside lot with mound, and a slotted floor warm confinement building. In their warm building, the fresh air was drawn through a plenum chamber in the attic and, hence, into a ceiling duct. Exhaust fans were located in the walls and in the manure pit. In addition, a heating unit was installed at the north end of the duct to permit warming of the outside air and to combat any fogging effect during extremely cold weather. The pit fans operated continuously and the wall fans operated in reponse to thermostats.

The major disadvantage of confinement buildings is the high initial investment. The facility costs can be balanced with reduced labor requirements and increased animal performance. Automated capabilities for handling and disposal of the waste materials and containment of total animal wastes decrease pollution potentials.

EVALUATION OF WASTE MANAGEMENT SYSTEMS

The selection of feeding facility design and waste management system should be made with regard to the effect on the environment and the

TABLE II-2

A COMPARISON OF FIVE HOUSING SYSTEMS FOR FEEDLOT CATTLE IN WEST CENTRAL MINNESOTA (2)(30)

	Conventional		Manure Scrape		Cold Slot		Warm Slot		Open Lot
Sq. ft./head	30	20	30	20	25	17	25	17	250
Av. lb. bedding per day per head	2.16	1.98	2.70	2.49					
Av. daily gain, lb.	2.15	2.05	2.16	2.26	2.21	2.14	2.33	2.33	2.04
Av. daily dry feed intake, lb.	13.22	13.54	13.76	13.78	14.16	13.90	14.78	14.16	13.35
Av. dry matter required per 100 lb. gain, lb.	616	660	638	610	641	650	634	608	654
No. head	200	300	200	300	204	300	204	300	300
No. days feeding to put on 560 lb. gain[a]	260	273	259	248	253	262	240	240	275

[a] Days of feeding to produce 560 lb. of gain from an initial weight of 436 lb. to a final weight of 996 lb.

ultimate disposal of the waste material. The system should not pollute the air, water, or land. Thus, in an ideal system the wastes are collected and satisfactorily treated and disposed of soon after they are received by the feeding floor. Disposal alternatives include recycling to crop land and/or livestock by reprocessing and refeeding.

Butchbaker et al. (6) have ranked waste management systems in regard to pollution control:

1. cable scraper, with shallow holding pit and treatment by means of lagoon and/or manure irrigation on pasture or crop land;
2. oxidation ditch treatment of the waste underneath a slotted floor building, with overflow going to a lagoon, and then manure irrigation;
3. a deep pit underneath a slotted floor feeding facility for cold or warm confinement building, slurry hauling with a soil injection system;
4. solid floor confinement, solid waste handling, composting or field application;
5. paved feedlot with a flushing system and manure irrigation;
6. unpaved feedlot with settling basins and detention reservoirs and irrigation of the runoff wastewater onto crop land; and
7. unpaved feedlot with detention reservoirs or lagoons only and dependent upon evaporation for removal of excess liquid waste.

The first four systems mentioned above are associated with confinement beef feeding barns. Although more costly than the open feedlot systems, they offer a higher potential for pollution control. The cable scraper system, oxidation ditch system, and flushing system can be used frequently to remove the waste material and reduce odors. Also, they provide the opportunity for using a nearly continuous flow system. The unpaved feedlots with detention reservoirs have the least degree of pollutant control. Detention reservoirs are subject to overflows when rainfalls are above the design rainfalls, some odors arise during certain periods of the year, and settleable solids may fill the reservoir.

REFERENCES

1. Anonymous, "Confinement Feeders: Check Your Scuba Gear," Feedlot, No. 12, p. 32, February 1970.

2. Bates, D. W., and L. K. Lindor, "The Influence of Housing on Gains of Beef Cattle in Five Different Structures," A.S.A.E. Paper No. 70-902, American Society of Agricultural Engineers, December 1970.

3. Beef Handbook, Housing and Equipment, Midwest Plan Service, Iowa State University, Ames, Iowa (1968).

4. Blair, T. A., Climatology, Prentice-Hall, Inc., N.Y. (1942).

5. Bond, T. E., R. L. Givens, and S. R. Morrison, "Comparative Effects of Mud, Wind and Rain on Beef Cattle Performance," A.S.A.E. Paper No. 70-406, American Society of Agricultural Engineers, July 1970.

6. Butchbaker, A. F., J. E. Garten, G. W. A. Mahoney, and M. D. Paine, "Evaluation of Beef Cattle Feedlot Waste Management Alternatives," Water Pollution Control Research Series, 13040FXG 11/71, EPA, OR&M, 321 pp., November 1971.

7. Esmay, M. L., Principles of Animal Environment, The AVI Publishing Co., Inc., Westport, Connecticut (1969).

8. Gilbertson, C. B., T. M. McCalla, J. R. Ellis, O. E. Cross, and W. R. Woods, "The Effect of Animal Density and Surface Slope on Characteristics of Runoff, Solid Wastes and Nitrate Movement on Unpaved Beef Feedlots," Bulletin SB 508, Agricultural Experiment Station, University of Nebraska, Lincoln (1970).

9. Givens, R. L., "Height of Artificial Shades for Cattle in the Southeast," Transactions of the A.S.A.E., No. 8, pp. 312-313 (1965).

10. Givens, R. L., S. R. Morrison, W. N. Garrett, and W. B. Hight, "Influence of Feedlot Pen Design and Winter Shelter of Beef Cattle Performance," *California Agriculture*, No. 22, pp. 6-7, February 1968.

11. Grub, E. W., R. C. Albin, D. M. Wells and R. Z. Wheaton, "The Effect of Feed, Design, and Management on the Control of Pollution from Beef Cattle Feedlots," *Animal Waste Management*, Cornell University Conference, pp. 217-224, Syracuse, New York, January 13-15, 1969.

12. Grub, E. W., R. C. Albin, D. M. Wells, and R. Z. Wheaton, "Engineering Analysis of Cattle Feedlots to Reduce Water Pollution," *Transactions of the A.S.A.E.*, No. 12, pp. 490-492, 495 (1969).

13. Grussing, Don, "Shelter Pay_____?" *Feedlot*, No. 12, pp. 30-32, 34, 35, February 1970.

14. Hart, S.A., "The Management of Livestock Manure," *Transactions of the A.S.A.E.*, No. 3, pp. 78-80 (1960).

15. Hellickson, M. A., W. B. Witmer, and R. Barringer, "Comparison of Selected Environmental Conditions and Beef Cattle Performance in Pole Type and Closed Environment," A.S.A.E. Paper No. 70-901, American Society of Animal Science, Chicago, Illinois, November 29, 1968.

16. Henderson, H. E., and M. R. Geasler, "Effect of Environment and Housing on the Performance of Feedlot Cattle Under Midwest Conditions," Paper presented at Midwestern Sectional Meeting, American Society of Animal Science, Chicago, Illinois, November 29, 1968.

17. Hoffman, M. P., and H. L. Self, "Shelter and Feedlot Surface Effects on Performance of Yearling Steers," *Journal of Animal Science*, No. 31, pp. 967-972, November 1970.

18. Ittner, N. R., T. E. Bond, and C. F. Kelly, "Methods of Increasing Beef Production in Hot Climates," California Agricultural Experiment Station, Bulletin 761, April 1958.

19. Johnson, D. W., "Survey of Feeding Beef Cattle Inside Sheds," A.S.A.E. Paper No. 70-905, American Society of Agricultural Engineers, December 1970.

20. Kelly, C. F., "Effects of Thermal Environment on Beef Cattle, Agricultural Engineering, No. 41, pp. 613-614, September 1960.

21. Kohler, M. A., T. J. Nordenson, and D. R. Baker, "Evaporation Maps for the United States," Technical Paper No. 37, Weather Bureau, U.S. Department of Commerce, Washington, D.C. (1959).

22. Kreis, R. D., M. R. Scalf, and J. F. McNabb, "Characteristics of Rainfall Runoff from a Beef Cattle Feedlot," Environmental Protection Technology Series, EPA-R2-72-061, September 1972.

23. Loehr, Raymond C., Pollution Implications of Animal Wastes--A Forward Oriented Review, Robert S. Kerr Water Research Center, FWPCA, USDI, Ada, Oklahoma (1968).

24. Morrison, S. R., V. E. Mendel, and T. E. Bond, "Sloping Floors for Beef Cattle Feedlots," Management of Farm Animal. Proceedings of National Symposium, May 5-7, (1966), pp. 41-43, published by American Society of Agricultural Engineers, St. Joseph, Michigan.

25. Nelson, G. L., "Effects of Climate and Environment on Beef Cattle," Agricultural Engineering, No. 40, pp. 540-544, September 1959.

26. Pratt, G. L., "Confinement Beef Housing for Air and Water Pollution Control in Cold Climates," Paper presented at the Conference of General Collaborators from North Central Agricultural Experiment Stations at the Northern Utilization Research and Development Division, Peoria, Illinois, March 23-24, 1970.

27. Pratt, G. L., and G. L. Nelson, "Structural Analysis of Floor Grids for Confinement Cattle Feeding Systems," Transactions of the A.S.A.E., No. 11, pp. 50-53 (1968).

28. Pratt, G. L., R. E. Harkness, R. G. Butler, J. L. Parson, and M. L. Buchanon, "Treatment of Beef-Cattle Waste Water for Possible Re-Use," Transaction of the A.S.A.E., No. 12, pp. 471-473 (1969).

29. Schulz, A. H., "Basic Requirements for Beef Cattle Housing, Feeding, and Handling," Agricultural Engineering, No. 41, pp. 615-617, September 1960.

30. Smith, R. E., H. E. Hanke, L. K. Lindor, R. D. Goodrich, J. L. Meiske, and D. W. Bates, "A Comparison of Five Housing Systems for Feedlot Cattle," Research Report B-136, West Central Experiment Station, University of Minnesota, Morris, Minnesota (1970).

31. "Two to Ten Day Precipitation for Return Periods of 2 to 100 Years in the Contiguous United States," Technical Paper No. 49, Weather Bureau, Department of Commerce, Washington, D.C. (1965).

32. Van Fossen, Larry D., and Vernon M. Myer, "Feeding Systems are Long-Term Investments--Choose Wisely," Beef, pp. 24-26, June 1969.

SECTION III

BEEF FEEDLOT SITE SELECTION

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SECTION III

BEEF FEEDLOT SITE SELECTION

Many considerations influence the selection of a feedlot site which will be suitable for adequate pollution control and protection of the surrounding environment. These considerations may be grouped into six categories: Regulations, Spatial Requirements, Topographic Features, Microclimates, Soils and Geologic Structures, and Social Considerations. Although these categories are interrelated, each will be discussed individually.

REGULATIONS

Laws written to protect each individual in our society have been passed at nearly all levels of government. Regulations imposing responsibility for the quality of the environment and the use of both renewable and depletable resources have been imposed on all who use these resources. This involvement has placed a responsibility for pollution control and environmental enhancement on each individual and corporation presently designing, developing, or managing a livestock feeding facility. State and local regulations should be carefully studied since they will, in most instances, affect feeding facility site selection. Several states have placed restrictions on the minimum distance that a feedlot can be located from surface water, residential dwellings, municipalities, recreation areas, and arterial highways. Other states are considering similar courses of action. Additional requirements now in effect may include storm water runoff control facilities, ground water contamination prevention structures, solid and runoff-carried wastes storage facilities, and specified ultimate disposal procedures. In most cases, these regulations are controlled by statutory permits issued through appropriate agencies within state and/or local governments. A list of state agencies to be contacted is included at the end of this section. Additional information concerning zoning and other local restrictions may be obtained from the county officials serving the immediate district.

SPATIAL REQUIREMENTS

The spatial needs of various livestock feeding units will vary with the facility types and climatic conditions. The total area required for an integrated system may be determined as the sum of the areas required for each of the following components:

1. the production area,
2. extraneous storm water runoff diversion ditches,
3. storm water runoff collection and retention structures,
4. wastes storage, treatment, and ultimate disposal sites, and
5. buffer zone around the feeding facility and/or ultimate disposal site.

Estimates for the area needed by each of the above components are discussed in more detail in the following subsections.

Production Area

The production area requirements can be based on the pen area. Pen area designs vary from 20 to 200 square feet per animal. An additional 15 percent of the pen area is needed for alleyways, feed bunks, and animal shipping and receiving docks. Mills, scales, office, housing, driveways, and parking space require an additional tract 20 to 30 percent of the pen area size.

Extraneous Storm Water Runoff Diversion Ditches

Extraneous storm water runoff diversion ditches are constructed to reduce the volume of contaminated runoff which must be collected and disposed of or treated. To prevent uncontaminated storm water runoff from contacting manure and other pollutants, diversion ditches should be constructed around all feeding, feed preparation and storage, solid manure storage, and runoff wastes retention areas. The amount of extraneous storm water runoff to be diverted may be reduced by selecting a site which has a minimum upslope drainage area. Nevertheless, overdesigning the capacity of the diversion structures (where rain storms of high intensity occur) could be an economical safety factor. In many areas these structures are built around covered facilities primarily to maintain a dry waste handling area near the facility. Runoff diversion structures generally require an area which is less than or equal to 5 percent of the total pen and runoff collection area.

Storm Water Runoff Collection and Retention Structures

Storm water runoff collection and retention structures are designed to retain and provide temporary storage for all storm water runoff which comes in contact with manure and other pollutants. The size of these structures is dependent on the rainfall of the region and resulting runoff from the facility. Since increased animal densities are possible on paved surfaces, smaller runoff control structures may be used on a paved open feedlot more successfully than on an unpaved lot having the same animal population. Several states regulate the size of sedimentation and retention ponds and the runoff retention time in each structure. These structures should, in the absence of regulation, be designed to retain at least all runoff resulting from the rainfall from a 10-year 24-hour design storm or its equivalent. The area needed for these structures will range from 2 to 15 percent of the total pen area depending on structure depth and volume of rainfall resulting from the design storm.

Wastes Storage, Treatment, and Ultimate Disposal Sites

Wastes storage, treatment, and ultimate disposal sites are a major concern when computing the area needs for beef animal production units. The amount of acreage required for these uses will depend on the volume and moisture characteristics of the wastes generated, which, in turn, are dependent on the type of facility and wastes management system design. Both runoff and solid manure wastes are generated from open feedlots. On the other hand, wastes generated from total confinement facilities are in the form of a slurry which contains both manure and urine. The volume of these slurries which must be treated or disposed of is controlled by the number of animals on feed, type of feed, and, in some instances, by the volume of dilution water added. The amount of solid manure wastes produced in open feedlots is dependent on the number of animals, type of feed, and pen surface moisture conditions; volume of runoff wastes originating from open feedlots is dictated by drainage area, amount and intensity of precipitation, and pen surface conditions.

Three wastes management facilities will be discussed according to moisture characteristics: (a) runoff wastes, (b) solid manure, and (c) slurry wastes.

Although the basic site selection concepts concerning waste management are applicable to beef production facilities, these precepts should be considered for the entire animal production industry.

Runoff Wastes. Runoff wastes control involves the integration of runoff retention and storage structures with a treatment method and a means of disposal. The land area requirements of runoff retention have been previously discussed.

Because of the extreme pollution potential of animal wastes, conventional municipal waste treatment designs are not considered to be economically feasible for use by beef cattle feedlot operators without significant modifications.

Spray runoff treatment, a promising treatment method recently demonstrated, may be used to treat runoff in areas where freezing conditions exist for less than two months during the year. The land area needed for this method ranges from 20 to 50 percent of the pen area plus an additional 15 percent for a pretreatment storage structure.

Irrigation of crops, pasture, or wooded land is the most practical means of runoff disposal in most climates. Desirable application rates appear to range from 4 to 8 inches per year. The land area needed for irrigation of runoff is equal to the volume of runoff generated divided by the appropriate annual application rate. The spatial requirements of a runoff irrigation system must often include a preirrigation storage pond to facilitate coordination of runoff applications with crop and soil moisture conditions and to avoid application of runoff to frozen or snow-covered surfaces. The acreage required for this storage pond will range from 0.1 to 0.3 times the pen area. Maximum runoff disposal rates may be necessary during periods of extreme weather conditions resulting in occasional crop damage.

Areas in the western United States, where the moisture deficit (evaporation minus precipitation) is greater than 10 inches, have a high potential for using evaporation for ultimate disposal of liquid wastes. An evaporation pond area approximately one-third the size of the total feedlot will be needed in a region of a 40-inch moisture deficit. When considering this disposal method, the potential for groundwater contamination and other problems must also be investigated.

The following equations may be used to estimate the total area needed to utilize runoff wastes management systems incorporating irrigation or evaporation disposal techniques and spray runoff treatment methods. Annual runoff from feedlots may be 2 or 3 times that of adjacent cropland. Annual runoff values for a specific location may be obtained from the local office of the Soil Conservation Service or from a consulting engineer.

Irrigation Disposal

$$A_r = P + \frac{V}{R} + S \quad \text{.................................} \quad \text{EQN (III-1)}$$

where: A_r = total area for waste management, a.

P = area of runoff retention structure, a.

V = annual runoff volume, a-in.

R = application rate, in./yr.

S = additional area for disposal, a.

$$A_r = 0.02 \text{ to } 0.15(\text{pen area}) + \frac{\text{a-in. runoff/yr.}}{4 \text{ to } 8 \text{ in./yr.}} + 0.05 \text{ to } 0.15(\text{pen area})$$

Spray Runoff Treatment

$$A_r = P + T + S + E \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad \text{EQN (III-2)}$$

where: A_r = total area for waste management, a.
P = area of runoff retention structures, a.
T = treatment area, a.
S = additional area for disposal, a.
E = emergency irrigation disposal area, a.

$$A_r = 0.02 \text{ to } 0.15(\text{pen area}) + 0.2 \text{ to } 0.5\ (\text{pen area}) + 0.05 \text{ to } 0.15(\text{pen area}) + 0.1 \text{ to } 0.2\ (\text{irrigation disposal area})$$

Evaporation Disposal

$$A_r = P + \frac{V}{D} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad \text{EQN (III-3)}$$

where: A_r = total area for waste management, a.
P = area of runoff retention structure, a.
V = annual runoff volume, a-in.
D = moisture deficit, in./yr.

$$A_r = 0.02 \text{ to } 0.15(\text{pen area}) + \frac{\text{a-in. runoff/yr.}}{\text{in./yr. lake evap.} - \text{in./yr. rainfall}}$$

Example: Assume that one wishes to build a 10,000-head capacity feedlot with 125 square feet per animal equaling 33 acres of pen area including feed bunks, alleyways, etc. in a 30-inch rainfall area with 6 inches of annual runoff and a 10-inch moisture deficit (40-inches evaporation per year). Considering the maximum space-consuming conditions, the estimated land area requirement for irrigation disposal using Equation (III-1) is 60 acres; for spray runoff treatment using Equation (III-2) is 37 acres; and evaporation disposal using Equation (III-3) is 25 acres.

Irrigation Disposal

$$\text{(III-1)} \quad A_r = 0.15(33) + \frac{6(33)}{4} + 0.15(33) \simeq 60 \text{ acres}$$

Spray Runoff Treatment

$$\text{(III-2)} \quad A_r = 0.15(33) + 0.5(33) + 0.1(33) + 0.2(60) \simeq 37 \text{ acres}$$

Evaporation Disposal

$$\text{(III-3)} \quad A_r = 0.15(33) + \frac{6(33)}{10} \simeq 25 \text{ acres}$$

Solid Manure. Solid manure generated from animal feedlots is one of the most critical wastes disposal problems confronting the animal feeding industry. The lack of long-term site availability for solid manure disposal can create an impassible obstacle to efficient feedlot operation. Land application of solid manure, as with runoff, is the most practical method of disposal presently known. The selection of a feedlot site should include extensive investigation of the land area available for manure disposal.

Fewer problems will be encountered by the feedlot owner who owns sufficient land area for manure disposal. However, total ownership of disposal areas, especially with larger lots (5,000 to 10,000 head plus), may not be practical, and firm advance commitments for manure disposal should be obtained before the first land purchase or construction dollar is spent. For example, these commitments, which would be in the best interest of all concerned parties, may be in the form of land leases with renewal options or cooperative contracts between feedlot owners and grain growers. These may require grain growers to accept or buy an allotment of manure in return for special grain prices or manure hauling and spreading services.

The amount of land area needed for solid manure disposal is equal to the amount of manure cleaned from the feed pens divided by the application rate. The amount of beef cattle manure cleaned from feed pens ranges, on a dry weight basis, from 6.5 to 12.0 pounds per day per animal, depending on animal size, amount of roughage in the feed, and the percentage of soil removed from the pen surface with the manure. The amount of manure to be handled and the disposal land area may be reduced by carefully cleaning the pens to leave from 2 to 3 inches of manure packed on the pen surface, thus reducing the amount of soil to be handled with the manure.

The quantity of manure cleaned from a feedlot may be estimated by using the following equation:

$$M = \frac{An \times W}{2000} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad \text{EQN (III-4)}$$

where: M = dry weight of manure produced, tn./yr.
An = animal days/yr.
W = weight of manure produced/animal/day, lbs.

$$M = \frac{\text{365 days/yr. (feedlot head capacity) (6.5 to 12.0 lbs. manure/animal day)}}{\text{2000 lbs./ton}}$$

Example: Assuming that each animal produces a dry weight equivalent of 12 lbs. of manure daily, the solid manure cleaned from a 10,000 head beef feedlot in one year according to Equation (III-4) equals approximately 21,900 tons.

$$\text{(III-4)} \quad M = \frac{365(10{,}000)(12)}{2{,}000} = 21{,}900 \text{ tons/yr.}$$

The application rate of solid manure ranges from 10 to 40 tons dry weight per acre depending on the type of crops, soil types, and rainfall amounts. The amount of land area required to dispose of solid manure "A_m" may be estimated using the following equation:

$$A_m = \frac{M}{R} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{EQN (III-5)}$$

where: A_m = solid manure disposal area, a.
M = volume of manure, tn./yr.
R = application rate, tn./a./yr.

Example: Using the 21,900 tons of manure produced on a 10,000 head capacity feedlot, which was estimated in the preceding example, and a 10 ton/acre/year manure application rate (Figure III-1) the estimated acreage required for manure disposal by using Equation (III-5) is 2,190 acres.

$$\text{(III-5)} \quad A_m = \frac{21{,}900}{10} = 2{,}190 \text{ acres}$$

Frequent pen cleaning and disposal by direct application to crops can eliminate the need for solid wastes storage. However, the seasonal nutrient needs of crops and soil moisture conditions in wetter or colder climates do not correspond to a systematic schedule of wastes disposal by land application. The application of solid wastes to saturated or frozen soils will, like feedlot runoff, create a contaminated storm runoff problem from the disposal site. Thus, solid wastes storage is a necessity in most climatic and agricultural regions. There is wide variability in the factors which influence the land area needed for this type of storage. In general, one should consider a storage area approximately 15 to 20 percent of the feed pen area in size and suitable for the construction of a storage structure which will eliminate surface and groundwater pollution.

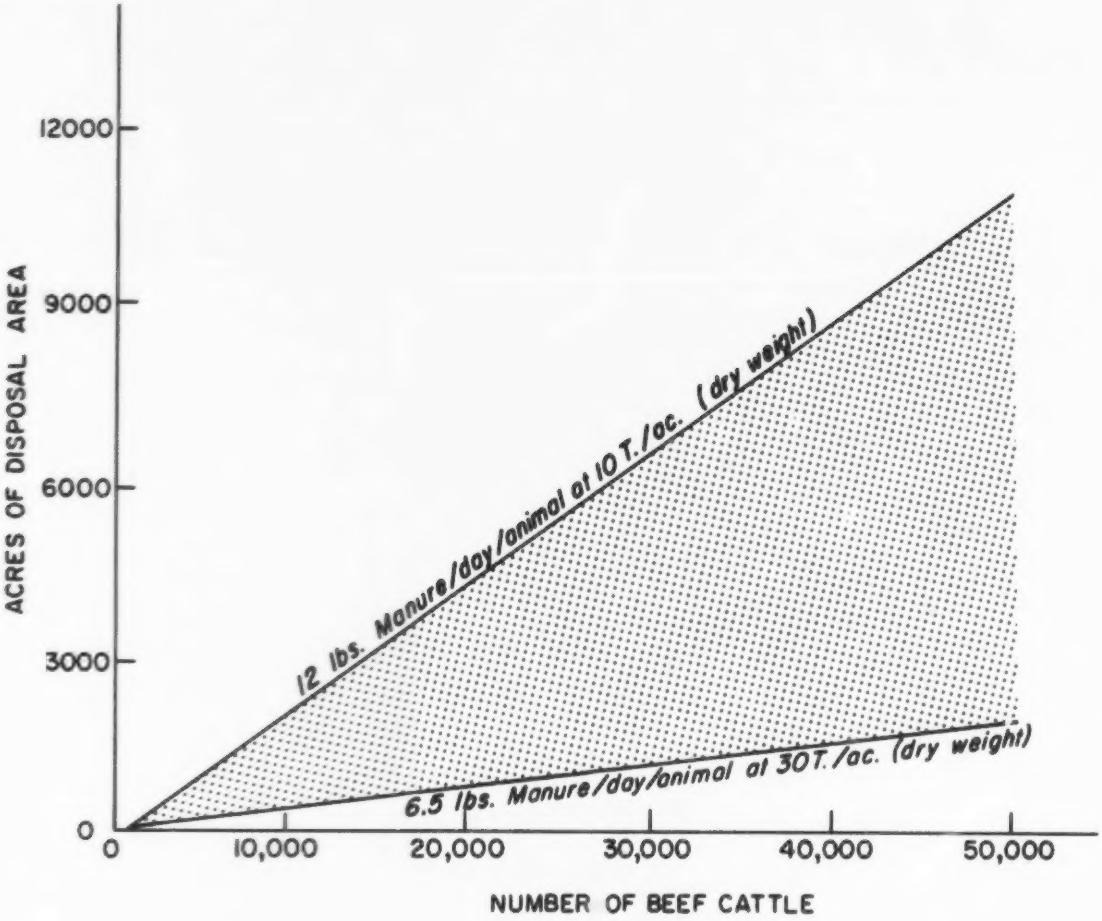

FIGURE III-1. LAND AREA REQUIREMENTS FOR DISPOSAL OF SOLID MANURE WASTES

Slurry Wastes. Slurry wastes are most commonly produced in total confinement buildings with slotted floors and in concrete open feedlots with flush type manure removal. Slurries are generally scraped, flushed, or pumped from the pen area at regular intervals ranging from daily to monthly. Thus, specially designed storage structures are a necessity to maintain environmental quality between disposal periods. Storage tanks should be covered to reduce odors and prevent children and animals from become trapped in them. For a given storage volume, tanks which have straight sidewalls require less area than lagoons which are usually designed with sloping sides. Mechanically aerated oxidation ditches are also used for slurry manure storage and have been successfully used directly under the slotted floor in hog confinement buildings where they do not require additional land area. The primary advantage of using this process is odor reduction.

The basic equations used to estimate spatial requirements for solid manure disposal on cropland may be used in estimating the area needed for slurry disposal. Manure slurries are a total composite of manure, as excreted, without the changes caused by rainfall leaching. Soil application rates, for this reason, should be reduced from the 10 to 40 tons per acre suggested for solid manure wastes to 10 to 20 tons per acre. Additionally, the daily amount of manure produced is approximately 60 pounds per animal. The end result of the decreased application rate and greater amount of manure to be handled is a significant increase in the size of the disposal area.

The required amount of land for both solid and slurry wastes disposal may be greatly reduced by increasing the rate and/or frequency of application; however, this should be done only if the feeder has control of the crops or the land either by leasing or through ownership. This approach, in some cases, is uneconomical, but firm wastes disposal agreements should be obtained from neighboring landowners before the final decision is made on a site.

The distance that wastes must be hauled for disposal should be kept to an economically feasible minimum. The economic break point for hauling distance may be estimated as follows:

$$D = \frac{F - L - S + M - M^1}{H} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ \text{EQN (III-6)}$$

where: D = maximum economic hauling distance, mi.
F = value of chemical fertilizer with equivalent nutrient value, \$/tn.
L = loading costs, \$/tn.
S = spreading costs, \$/tn.
M = price paid farmer by feedlot owner to accept manure, \$/tn.
M^1 = price paid feedlot owner by farmer for manure, \$/tn.
H = hauling costs, \$/tn./mi.

Example: Assume that the nutrient content of a ton of manure is equivalent to \$4.00 worth of commercial fertilizer, that it costs \$0.35 per ton to load and \$0.90 per ton to spread manure, that the manure hauling can be contracted for \$0.10 per ton/mile and that the amount paid by the farmer to the feedlot owner for the manure is \$1.50 per ton. Then according to Equation (III-6) the maximum economical hauling distance is 12.5 miles.

$$\text{(III-6)} \quad D = \frac{\$4.00 - \$0.35 - \$0.90 - \$1.50}{\$0.10 \text{ per mile}} = \frac{\$1.25}{\$0.10} = 12.5 \text{ miles}$$

A manure irrigation system for pumping a slurry or waste water for field application costs about one-half as much as mechanically hauling and spreading a slurry within one-half mile of the feeding facility. Thus, a site with an area suitable for irrigating slurries within this distance could result in considerable savings for manure disposal.

Buffer Zone (Green Belt) Around the Feeding Facility

The basic purpose of developing a buffer zone is to reduce or eliminate the probability of nuisance complaints from the general public. Feedlot operations, in many states, have received nuisance complaints resulting from odors produced by their facilities. Specifically, to mention only a few, beef cattle feedlots in Arizona, Texas, and Kansas and a hog feedlot in Missouri have received court decisions which were in favor of the plaintiffs; some decisions have resulted in cease and desist orders.

Where odors may be of concern, the buffer zone can approximate the configuration of an egg with the facility and all odor producing processes centered near the small end (Figure III-2). The actual orientation of the axis of the area is dependent upon the direction of the prevailing wind. The size of the buffer zone, usually from 4 to 20 miles along its long axis, is dependent on the size of the feeding operation and type of manure management employed. Obviously, good drainage and housekeeping practices, coupled with a prompt disposal schedule, may significantly reduce the intensity of odors and thus reduce the size of the buffer zone. In some locations, zoning agreements may be finalized with local governing bodies. Zoning may stipulate a specific distance from the operation or a group of feeding operations reserved for agricultural uses. Such agreements would allow protection against legal action from residential and recreational development after a feeding operation is established.

Enough space should be allowed around the facility to provide a "green belt." The size of this area need not be expansive but should be large enough for a shelter belt or visual improvement vegetative plantings. Some of this area will be the same as that used for waste disposal or other feedlot operations. The concept is especially important in areas where the operation may be seen from major arterial highways.

TOPOGRAPHIC FEATURES

Topography (lay of the land) plays an important role in two respects for selection of a feeding site. The slope and natural drainage to surface waters of any given parcel of land governs its value as a feeding site.

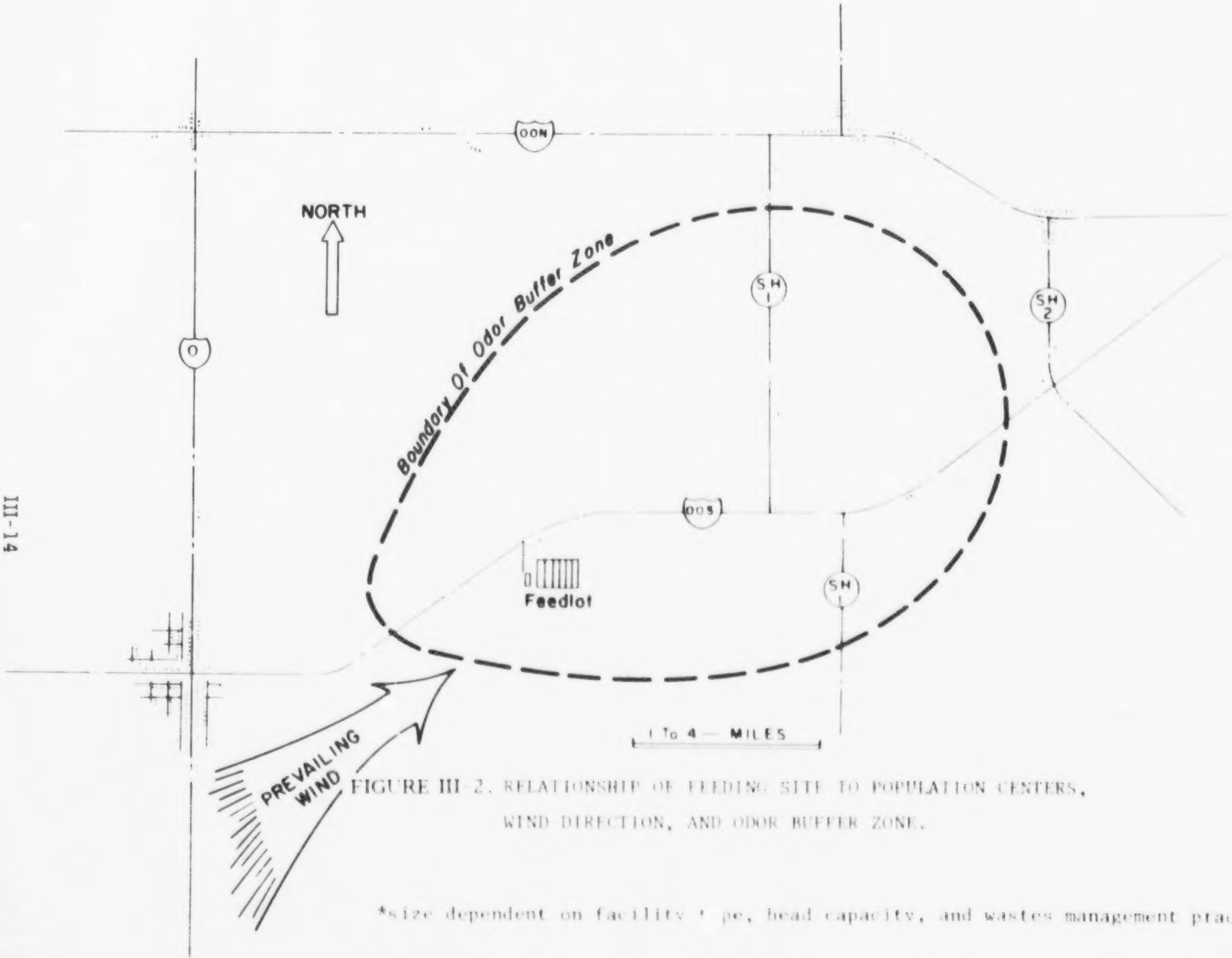
NORTH
OON
O
SH 1
SH 2
OOS
SH 1
Boundary Of Odor Buffer Zone
Feedlot
PREVAILING WIND
1 To 4 — MILES

FIGURE III-2. RELATIONSHIP OF FEEDING SITE TO POPULATION CENTERS, WIND DIRECTION, AND ODOR BUFFER ZONE.

*size dependent on facility type, head capacity, and wastes management practice

Land which is too flat may be poorly drained, and poor drainage results in sloppy pen conditions and increased probability for groundwater contamination. On the other hand, surface runoff is difficult to control on land with extreme gradients. The second role that topography plays in site selection is basically one of economics. Feeding facilities are readily adaptable to sites which, for topographical reasons, are marginal for most intensive farming. Because of the marginal classification, these lands often are priced at a much lower dollar value than is land used for intensive farming. The rugged topography of these sites may create a need for a large amount of earth moving; however, there are earth moving requirements associated with all feeding sites regardless of topography. Additional earth moving costs should be balanced with the lower land costs.

Topographical quadrangle maps in the 7.5 or 15.0 minute series are available for most of the United States from the United States Geological Survey. Accurate information concerning the contour of the land and its location with respect to watercourses, access routes, residential areas, and recreational areas may be obtained by careful inspection of these maps. Preliminary planning layouts for several different sites may be made on topographical maps before making final site selection decisions. After selecting a site, the consultant should make a topographical survey with a contour interval of 1 or 2 feet to expedite the detailed designing of the facility and processes.

During the evaluation of the topographic suitability of sites, one should eliminate all those which do not meet, or cannot be adapted to meet, the following constraints:

1. a minimum of land uphill which will contribute extraneous runoff;
2. a slope for the feed pens with a 2 to 6 percent gradient (sloppy pen conditions may occur with less than 2 percent pen slope, and uncontrollable runoff may occur with greater than 6 percent pen slope);

3. space with suitable slope and deep soils for construction of runoff collection and storage facilities;
4. a manure storage area located away from natural drainage channels and having soil, bedrock, and a deep groundwater table;
5. a dry feedlot access route which may be easily maintained for manure removal during all weather conditions (access roads through low wet areas or with steep gradients will cause manure removal problems during wet and freezing weather); and
6. a low gradient site for runoff disposal which is located away from natural drainage areas.

Not all of the above constraints will apply to total confinement and certain other facility designs, but each should always be considered when appropriate.

A final topographical consideration for site selection is the location of a facility with respect to surface waters. Several states have promulgated control requirements based on specific distances or have developed mathematical formulae to be followed when locating near surface waters. This distance will not remove the pollution potential to a surface watercourse since travel in a drainage channel will not significantly treat the pollutants in the feedlot runoff.

In the absence of regulations, a realistic consideration is the selection of a site over which enough control can be exerted to prevent accidental contact of manure and waste water runoff with surface waters.

MICROCLIMATES

As discussed earlier, the site selection decisions associated with climate are mainly those related to the type of facility and the wastes handling method. However, the microclimate (ambient climatic or environmental conditions of a specific locale) of a prospective site may have some bearing on its acceptability. Three aspects of the microclimate of a locale are worthy of consideration. These are extremes in wind conditions, solar radiation, and precipitation.

Depending on major climatic conditions, wind affects the operation of a feeding facility in many ways. Too much wind causes dusty pen conditions in dry climates and drifting snow in cold climates. Inaccessibility and adverse comfort indexes can lead to reduced feed conversion efficiencies in cold climates. In a few instances, too little wind can cause animal discomfort in hot and humid areas and may contribute to sloppy pen conditions in cooler areas because of decreased evaporation potentials. Prevailing wind direction in any locale and upward and downward drafts in mountainous areas should be considered in the prediction of possible odor complaints (Figure III-3). Wind may be partially controlled by selecting a site protected by vegetative shelter belts or natural land forms. In the absence of natural protection in the North, artificial windbreaks have been successfully constructed along the windward side of feed pens.

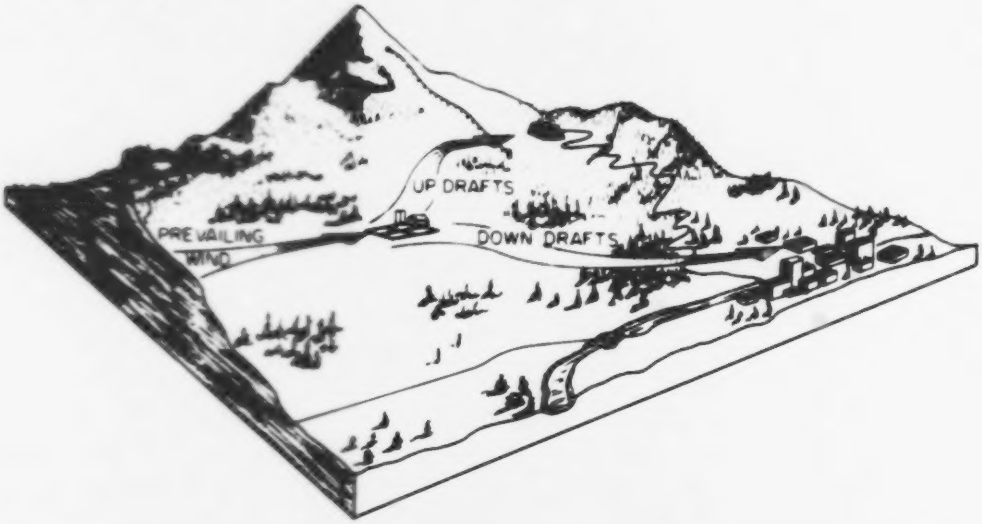

FIGURE III-3. RELATIONSHIP OF UPDRAFTS AND DOWNDRAFTS TO PREVAILING WINDS IN MOUNTAINOUS OR HILLY AREAS.

Solar radiation affects not only animal production efficiency but also waste management and pollution control facilities. The evaporation potential from a wet manure surface is determined by humidity, air movement, and solar radiation. Solar radiation may be somewhat controlled by selecting a site with respect to the sun's travel or providing the desired amount of shade. Feedlots located on northern or eastern slopes receive less intense sunlight, thus reaching maximum temperatures for shorter periods during the day than those located on southern or western slopes. Thus, feedlot sites on northern and eastern slopes are more desirable in warmer climates but require more shelter for the animals in colder climates. In warmer climates this location requires less control of the animal's environment. In colder climates the situation is reversed, and operations should be placed on southern or western slopes to obtain maximum temperature benefits for animal comfort. In these locations proper placement may extend the northerly range of wastes handling, treatment, and disposal processes which have minimum temperature (freezing) constraints.

Precipitation is more important in selection of the general region than it is in selection of a specific locality for location of a feedlot; however, in some regions rainfall may vary considerably (as much as 10 to 15 inches annually) over a very short distance. Snowfall amounts may also vary greatly in a short distance; thus care should be exercised to determine local snowfall amounts to avoid localities which are snowbound a portion of the year. This point may be insignificant for most of the country yet unquestionably important for specific localities which characteristically have large variance in annual precipitation.

The climate surrounding a feeding site does not affect the performance of animals fed in total confinement facilities. Accessibility is an important consideration of the effects of local climate on these facilities. Sites typified by drifting snow or dust and/or prolonged periods of wet or damp soil conditions tend to limit waste removal access; these should be avoided.

SOILS AND GEOLOGIC STRUCTURES

Soil types and the underlying geologic structure of each potential feeding site should be examined to insure maximum protection from groundwater pollution. Highly permeable loose soils, shallow soils over fractured bedrock, and shallow water tables should be avoided in pen areas, runoff and solid manure storage pits, and field disposal sites receiving high runoff and manure application rates. Contamination of groundwater is hazardous not only from the bacteriological standpoint but also from the threat of nitrate poisoning or methemoglobinemia (an oxygen-deprived condition in infants sometimes referred to as blue babies) which is caused by excessive amounts of nitrates in drinking water supplies. This malady afflicts livestock and humans (especially small children and pregnant females).

Present trends in some states are directed toward regulating the amount of infiltration or percolation from pen surfaces and liquid wastes impounding structures. An example is the maximum of 0.1 acre foot per acre per year which was recently proposed by one South Central state. Sites selected on heavy soils (fine-particled, expanding, or tight soils) with a low infiltration or seepage rate are, in most cases, ideal for construction of wastes retention and storage structures. The seepage from a structure may be determined, before use, by filling it with unpolluted water, allowing several days for sufficient saturation of the underlying soils, and measuring the water loss minus class A pan evaporation (lake evaporation on large structures). Seepage tests may be run, for purposes of site selection, on smaller scale by the use of small test ponds if a test pond bottom is at the same soil depth desired for the full scale structure.

In the absence of suitable soil conditions, soil sealing or concrete or asphalt liners can be included in the design of runoff control structures for a minimum of 300 dollars per acre. The advantage realized in careful site selection is, for this reason, economically important.

The depth of the water table is also important. A shallow aquifer is more vulnerable to contamination and should be avoided. In areas with fluctuating shallow water tables, concrete manure storage pits and confinement buildings designed with solid bottom manure pits may shift from their original position and suffer damage ultimately resulting in contamination of the aquifer.

Shallow water tables are also vulnerable to contamination when the land is irrigated with large amounts of pollutant-rich runoff waters; this damage is especially serious in areas of glacial till and within the flood plains of rivers, where water tables may be only inches below the surface and the soils are generally sandy or gravelly alluvium.

SOCIAL CONSIDERATIONS

Concern for environmental protection has resulted in state regulations and court actions which frequently lead to great expense for compliance. These actions have forced many feedlots to change their methods of operation, and a few have had to reestablish at a more suitable site or go out of business. Environmental controls have not only been placed on surface and groundwater pollution but also have included odor nuisances. Feedlots have had restraints placed on them solely on the basis of odor complaints from their neighbors.

Strong demands from the general public for increased meat production and improved meat quality do not offset the attendant problems with any lessened demand for environmental improvement. Animal production units seldom yield any monetary benefits directly to the complainants who will not accept disagreeable odors around their residences, places of work, or recreational areas. In many cases, odors may become such a nuisance to individuals that life patterns and established transporation routes are changed to avoid them. This circumstance is not unique to the animal feeding industry but is observed in a great many industrial operations such as oil and gas production, slaughterhouses, and chemical and plastics manufacturing. All of these industries are feeling the effects of public pressure to eliminate nuisances created by odors, sound, and unsightliness.

The successes of odor control efforts utilizing chemical deodorizers and odor masking agents have been questionable. In many cases, where application of chemicals has masked odors, the measures were temporary and the odors of some of the chemicals were as disagreeable as the manure odors. Perfumed aerosols have been used with some success for short distances in Southwestern states; however, the odors of manure are generally more persistent than the aerosols tested and are easily detected long distances from the source.

The best odor controls are, at present, a policy of good housekeeping coupled with proper pen design and careful feeding site selection. Regular manure removal and disposal and very short runoff retention times can significantly reduce the amount of odor produced. A minimum pen slope of 2 percent enhances adequate drainage and reduces sloppy pen conditions and resulting odors. Manure slurry storage in oxidation ditches produces less odor than anaerobic storage pits. In the Northeast, anaerobic storage pits have been covered to reduce the amount of odor.

In recent years, there has been a successful advance of programs for "national beautification." In short, these programs require the use of privacy fences to conceal such unsightly places as junk yards, dumps, freight yards, and salvage yards from public view. In the forseeable future, unsightliness and noise emission from livestock feeding operations may bring about public-initiated court actions. The selection of a site with vegetative shelter belts and/or land formations suitable for visual concealment purposes or one located a sufficient distance from highways may prevent problems which do not yet exist.

The selection of a site should include consideration of prevailing wind direction, distance from residential areas and public gathering places, and the attitudes of immediate neighbors. Agreements for free manure application and/or a steady market for neighbors' grain or hay in return for freedom from nuisance complaints may have merit.

Zoning may be used effectively in some areas to prevent the encroachment of residential, shopping, and recreational areas. A very expensive but positive approach to zoning would be the purchase of enough land to create a buffer zone between the animals and society.

The task of co-existing with society will be resolved by locating a site which is remote from the greatest possible number of potential complainants, by isolation through controlling as much surrounding area as possible, and by developing public relations.

PRACTICAL APPLICATION

Changes in the attitudes and interests of the people of this and many nations over the world have aroused a much needed awareness of our surroundings and the heritage that we are leaving behind for future generations. This awareness has created a need for changes in disposal methods for industrial and agricultural wastes. Early in the past decade, wastes disposal practices which were recommended as acceptable included locating feeding sites on steep slopes and near streams or lakes for natural drainage and disposal of runoff wastes in surface waters. Recommended manure disposal practices included filling ravines and ditches, from which the manure eroded and washed into the streams. Little concern existed for contamination of groundwater supplies except where obvious damage would occur to the water supply for the feeding facility.

A typical beef feedlot layout is depicted in Figure III-4. The wastes management design used here may have been a recommended practice as late as ten years ago. The extent of environmental unbalance created by the various practices utilized in this operational plan was, in reality, unnecessary but economical. Relocation of the facility on

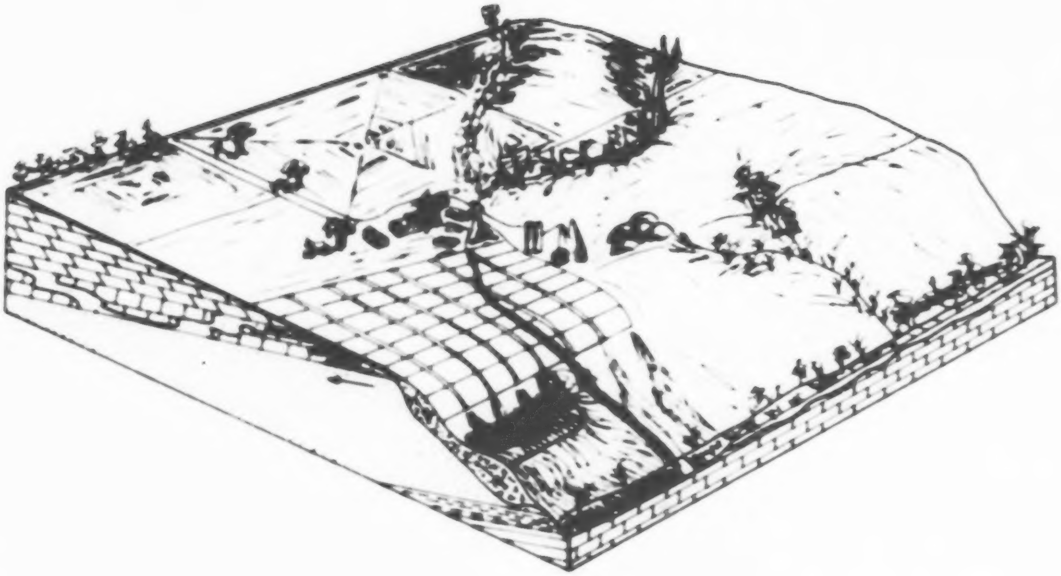

FIGURE III-4. TYPICAL BEEF FEEDLOT LAYOUT INCORPORATING OUTMODED DESIGN CONCEPTS

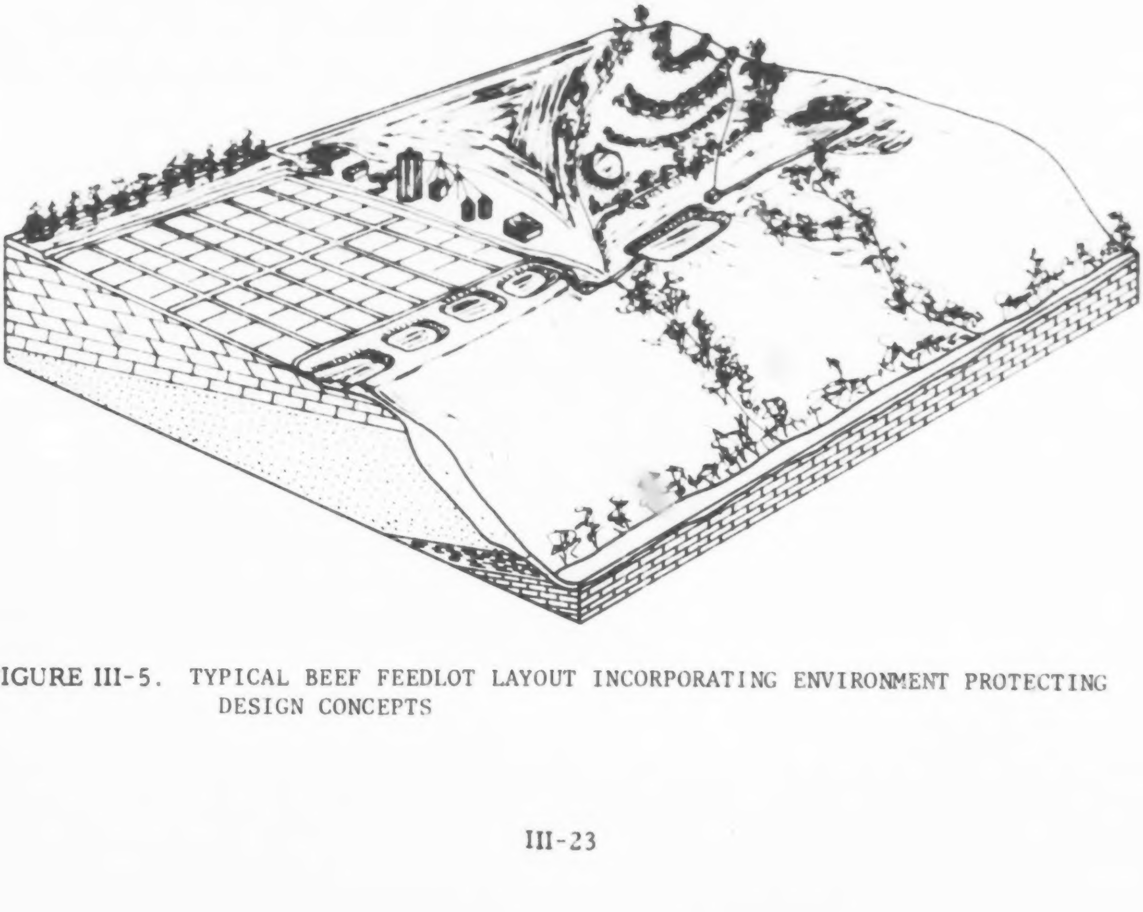

FIGURE III-5. TYPICAL BEEF FEEDLOT LAYOUT INCORPORATING ENVIRONMENT PROTECTING DESIGN CONCEPTS

the same site and seven changes of minor economic significance (which included addition of a few wastes handling and management facilities) could have eliminated most environmental hazards.

The same beef feedlot relocated on the same site is depicted in Figure III-5. This operation was planned with the use of the present environment-protecting concepts of site selection and wastes management. The pen area has been moved onto the more level land, which has clay soil underlaid with a solid dolomite rather than the sandy soil and cavernous limestone which is present on the hill slope. The new site is located away from the small creek and takes advantage of the vegetative shelter belt both as a shield against cold north winds and as a visual screen from the road. A ditch to divert extraneous drainage has been constructed around the pen area, and runoff collection ponds have been added across the lower end of the pens. The runoff from the collection ponds is pumped into a holding pond, from which it is distributed onto a pastured area with a large irrigation gun or metered onto a spray runoff treatment slope. The pens are cleaned regularly and the manure is temporarily stored or immediately hauled away and disposed of on agricultural land.

The actual application of good site selection principles is a matter of common sense and the ability to apply existing state regulations. There are no standard numerical guidelines and mathematical formulae applicable to each site selection in every part of the country. This section has been a compilation of the major site selection considerations which are representative of a large percentage of facility designs and geographic locations. Professional assistance from consulting engineers and/or the governmental agencies listed in the appendices may be needed to solve unique site selection problems.

APPENDICES

Current research findings concerning animal wastes management, treatment, and disposal may be obtained by contacting:

The Environmental Protection Agency, National Animal Feedlot Wastes Research Program, Robert S. Kerr Environmental Research Laboratory, Box 1198, Ada, Oklahoma, 74820, or Agricultural and Marine Pollution Control Section, Applied Science and Technology Branch, Office of Research and Monitoring, Washington, D.C., 20460.

The state and local offices of the U.S. Department of Agriculture's Cooperative Extension Service, Soil Conservation Service, and Agricultural Research Service.

Climate and rainfall data may be obtained by request to the U.S. Department of Commerce, Weather Bureau Technical Papers from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. Microclimatic conditions may be obtained from local offices of the U.S. Weather Bureau.

Topographic maps may be obtained from the U.S. Geological Survey, Denver Distribution Section, Federal Center, Denver, Colorado, 80225, for those areas which lie west of the Mississippi River, and from the U.S. Geological Survey, Washington Distribution Section, Washington, D.C., 20242, for those areas which lie east of the Mississippi River.

Information concerning state regulations and permits may be obtained from the following state agencies:

Alabama. The Water Resources Division, Alabama Geological Survey; State Department of Public Health; Water Improvement Commission; Alabama Department of Agriculture and Industries; State Office Building, Montgomery, Alabama 36104.

Alaska. State Department of Health and Welfare, Division of Environmental Health, Pouch H, Juneau, Alaska 99801.

Arizona. The Arizona Livestock Sanitary Board, Capitol Annex-Room 322, Phoenix, Arizona 85007. The Sanitation Division, State Health Department, 4019 N. 33rd Avenue, Phoenix, Arizona 85029.

Arkansas. Arkansas Department of Pollution Control and Ecology, 8001 National Drive, Little Rock, Arkansas 72209.

California. The California Resources Agency, State Water Resources Control Board, 1416 9th Street, Sacramento, California 95814.

Colorado. The Water Pollution Control Division, State Department of Health, 4210 East 11th Avenue, Denver, Colorado 80220.

Connecticut. The Dairy Division, and The Water Resources Commission, State Department of Agriculture and Natural Resources, 165 Capitol Avenue, Hartford, Connecticut 06115. State Department of Health, 79 Elm Street, Hartford, Connecticut 06115.

Delaware. Water Resources Section, Division of Environmental Control, Department of Natural Resources, Natural Resources Building, Dover, Delaware 19901.

Florida. The State Department of Air and Water Pollution Control, 315 S. Calhoun Street, Tallahassee, Florida 32301. The Division of Health, State Department of Health and Rehabilitative Services, Box 210, Jacksonville, Florida 32201.

Georgia. The Industrial Waste Section, Georgia Water Quality Board and the Georgia Department of Public Health, 47 Trinity Avenue, S.W., Atlanta, Georgia 30334.

Hawaii. Hawaii State Department of Health, P. O. Box 3378, Honolulu, Hawaii 96813.

Idaho. Water Pollution Control Section, Environmental Improvement Division, Idaho Department of Health, Statehouse, Boise, Idaho 83701.

Illinois. Illinois Environmental Protection Agency, 215 S. First Street, Champaign, Illinois 61820.

Indiana. Industrial Waste Disposal Section, Indiana State Board of Health, 1330 West Michigan Street, Indianapolis, Indiana 46206. State Department of Natural Resources, State Office Building, 100 N. Senate Avenue, Indianapolis, Indiana 46204. The Air Pollution Control Division, State Board of Health, 1330 W. Michigan Street, Indianapolis, Indiana 46206.

Iowa. The Iowa Water Pollution Control Commission, Department of Health, Lucas State Office Building, Des Moines, Iowa 50319. The Iowa Natural Resources Council, Grimes State Office Building, Des Moines, Iowa 50319. The Environmental Engineering Service, Iowa State Health Department, Lucas State Office Building, Des Moines, Iowa 50319.

Kansas. The Division of Environmental Health, Kansas State Department of Health, and the Livestock Sanitary Commission, Animal Health Department, State Office Building, Topeka, Kansas 66612.

Kentucky. The Kentucky Water Pollution Control Commission; the Water Pollution Division and the Solid Waste Division, Kentucky Department of Health, 275 E. Main Street, Frankfort, Kentucky 40601. The Division of Livestock Sanitation, Kentucky Department of Agriculture Capitol Annex Building, Frankfort, Kentucky 40601.

Louisiana. The Louisiana Stream Control Commission, P. O. Drawer FC, University Station, Baton Rouge, Louisiana 70803. The Louisiana Livestock Sanitary Board, P. O. Box 44003, Capitol Station, Baton Rouge, Louisiana 70800. The Louisiana State Department of Health, State Office Building, P. O. Box 60630, New Orleans, Louisiana 70160.

Maine. Site Selection Program, Maine Environmental Improvement Commission, State House, Augusta, Maine 04330.

Maryland. The Maryland Department of Water Resources, State Office Building, Annapolis, Maryland 21404.

Massachusetts. The Water Pollution Control Division, Department of Natural Resources, 100 Cambridge Street, Boston, Massachusetts 02202.

Michigan. The Water Resources Commission, Department of Natural Resources, Steven T. Mason Building, Lansing, Michigan. The Air Pollution Control Section, Division of Engineering, State Department of Public Health, 3500 N. Logan, Lansing, Michigan 48914.

Minnesota. The Minnesota Pollution Control Agency, 717 Delaware Street, S.E., Minneapolis, Minnesota 55440.

Mississippi. Mississippi Air and Water Pollution Control Commission, P. O. Box 827, Jackson, Mississippi 39205.

Missouri. The Missouri Water Pollution Board and the Division of Health, State Department of Public Health and Welfare, 112 West High, P. O. Box 154, Jefferson City, Missouri 65101.

Montana. The State Department of Health, Helena, Montana 59601.

Nebraska. The Nebraska Water Pollution Control Council, State Department of Health, State House Station, Lincoln, Nebraska 68509.

Nevada. Bureau of Environmental Health, Division of Health, State Department of Health and Welfare, 201 S. Fall Street, Carson City, Nevada 89701.

New Hampshire. The State Department of Water Supply and Pollution Control, Prescott Park, 105 Loudon Road, Concord, New Hampshire 03301. The Division of Public Health, Department of Health and Welfare, 61 S. Spring Street, Concord, New Hampshire 03301.

New Jersey. The New Jersey Department of Environmental Protection, P. O. Box 1390, John Fitch Plaza, Trenton, New Jersey 08625.

New Mexico. The Environmental Services Division, State Department of Health and Social Services, and the Environmental Improvement Agency, P. O. Box 2348, Santa Fe, New Mexico 87501.

New York. Bureau of Industrial Waste, Division of Pure Waters, Department of Environmental Conservation, Albany, New York 12201. New York State Department of Health, 845 Central Avenue, Albany, New York 12206.

North Carolina. Water Quality Division, State Department of Water and Air Resources, P. O. Box 27048, Raleigh, North Carolina 27611.

North Dakota. The Division of Water Supply and Pollution Control, Environmental Health and Engineering Services, State Department of Health, Bismarck, North Dakota 58501.

Ohio. The Ohio Department of Health and the Ohio Water Pollution Control Board, P. O. Box 118, Columbus, Ohio 43216.

Oklahoma. Regulatory Services Division, Oklahoma State Department of Agriculture, 122 Capitol Building, Oklahoma City, Oklahoma 73105. Sanitation Division, Environmental Health Services, Oklahoma State Department of Health, 3400 North Eastern, Oklahoma City, Oklahoma 73105.

Oregon. The State Department of Environmental Quality, State Office Building, 1400 S.W. 5th Avenue, Portland, Oregon 97201.

Pennsylvania. The State Department of Environmental Resources, P. O. Box 2351, Harrisburg, Pennsylvania 17120.

Rhode Island. Environmental Health Services, State Department of Health, State Office Building, Providence, Rhode Island 02903.

South Carolina. The South Carolina Pollution Control Authority, Owen Building, 1321 Lady Street, P. O. Box 11628, Columbia, South Carolina 29211.

South Dakota. The South Dakota Committee on Water Pollution, State Office Building No. 2, Pierre, South Dakota 57501. State Department of Health, State Capitol, Pierre, South Dakota 57501.

Tennessee. Division of Stream Pollution Control, Tennessee Department of Public Health, Cordell Hull Building, Nashville, Tennessee 37219.

Texas. The Texas Water Quality Board, 1108 Lavaca Street, Austin, Texas. The Texas State Department of Health, 1100 W. 49th Street, Austin, Texas 78756. The Texas Air Control Board, 320 E. 53rd Street, Austin, Texas. The Texas Animal Health Commission, Sam Houston Building, Austin, Texas.

Utah. The Water Pollution Committee, Division of Health, State Department of Social Services, 44 Medical Drive, Salt Lake City, Utah 84113.

Vermont. The State Department of Agriculture and the Agency of Environmental Conservation, Montpelier, Vermont 05602.

Virginia. The Pollution Abatement Division, Virginia Water Control Board, P. O. Box 11143, Richmond, Virginia 23230.

Washington. State Department of Agriculture, General Administration Building, P. O. Box 218, Olympia, Washington 98501. The Water Resources Division, State Department of Ecology, General Administration Building, Olympia, Washington 98501.

West Virginia. The Sanitary Engineering Division, State Department of Health, Charleston, West Virginia 25305. The Division of Water Resources, Department of Natural Resources, Charleston, West Virginia 25305.

Wisconsin. The Department of Natural Resources, Box 450, Madison, Wisconsin 53701.

Wyoming. The Division of Health and Medical Services, State Department of Health and Social Services, State Office Building, Cheyenne, Wyoming 82001.

REFERENCES

1. Alexander, R. M., "Social Aspects of Environmental Pollution," Agr. Sci. Rev., Vol. 9, No. 1, pp. 9-18 (1971).

2. Anon., Two to Ten Day Precipitation for Return Periods of 2 to 100 Years in the Contiguous United States, Technical Paper No. 49, Weather Bureau, Department of Commerce, Washington, D. C. (1965).

3. Anon., Agricultural Waste in an Urban Environment, Conference Proceedings, New Jersey Department of Agriculture, Trenton, New Jersey (Sept. 1970).

4. Blair, T. A., Climatology, Prentice-Hall, Inc., Englewood Cliffs, New Jersey (1942).

5. Duffer, W. R., R. D. Kreis, and C. C. Harlin, Effects of Feedlot Runoff on Water Quality of Impoundments, Environmental Protection Agency, Water Pollution Control Research Series, Report No. 16080GGP07/71 (1971).

6. Fairbank, W. C., Waste Disposal Problems in Highly Populated Areas, Extension Agricultural Engineering, University of California, Riverside, California (1970).

7. Fish, H., "Water Pollution Prevention Requirements in Relation to Farm-waste Disposal," Proceedings of Symposium on Farm Wastes, Paper 6, University of Newcastle, pp. 38-43 (1970).

8. Happer, L., "Supreme Court Upholds Judgements in HBI Case," Mo. Ruralist, p. 12 (Jan. 23, 1971).

9. Kohler, M. A., T. J. Nordenson, and D. R. Baker, Evaporation Maps for the United States, Technical Paper No. 37, Weather Bureau, U. S. Department of Commerce, Washington, D. C. (1959).

10. Levi, D. R., and J. C. Holstein, "Stockmens-Liability Under the Missouri Nuisance-Law," Science and Tech Guide, University of Missouri-Columbia Ext. Div., Agr., Econ. File.

11. Levi, D. R., "Legal-Aspects Pertaining to Environmental Regulations in Pork-Production," American Pork Congress, Des Moines, Iowa (Mar. 3, 1971).

12. Miller, R. F., "Space Requirements and Dust Control for Feedlot Cattle," Calif. Agr., No. 16, pp. 14-15 (Dec. 1962).

13. Miner, J. R., "Environment's Challenge: Acceptance as a Neighbor or Rejection as a Nuisance," Feedlot, No. 13, pp. 14-15, 34 (May 1970).

14. Miner, J. R., "Raising Livestock in the Urban Fringe," Agr. Engr., No. 51, (12), pp. 702-703 (Dec. 1970).

15. Nelson, G. L., "Effects of Climate and Environment on Beef Cattle," Agr. Engr., No. 40, pp. 540-544 (Sept. 1959).

16. Paulson, D. J., "Commercial Feedlots - Nuisance, Zoning, and Regulations," Washburn Law Jour., Vol. 6, pp. 493-507 (1967).

17. Scalf, M. R., W. R. Duffer, and R. D. Kreis, Characteristics and Effects of Cattle Feedlot Runoff, 25th Annual Purdue Industrial Waste Conference, Lafayette, Indiana (May 1970).

18. Schwiesow, W. F., "State Regulations to Livestock Feedlot Design and Management December 1970," Bulletin 42-189, USDA, ARS (April 1971).

19. Stewart, B. A., et al., "Nitrate and Other Water Pollutants Under Fields and Feedlots," Jour. Env. Sci. and Tech., No. 1, pp. 736-739 (1967).

20. Walker, W. R., "Legal-Restraints on Agricultural-Pollution," Relationship of Agriculture to Soil and Water Pollution, Cornell University Conference on Agricultural Waste Management, Syracuse, New York (1970).

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RUNOFF CARRIED WASTES

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SECTION IV

RUNOFF CARRIED WASTES

This section is designed for those interested in control of runoff wastes created by precipitation on an open feedlot. The quality and quantity of the runoff are discussed. Methods for solid separation and runoff detention are outlined. Disposal systems are discussed at length and experimental treatment systems are reviewed for the reader's information.

Several researchers have reported data on the quality of runoff from cattle feedlots, among these are: Miner et al. (1966) (11), Miner, Lipper, and Erickson (1967) (12), Loehr (1969) (9), Grub et al. (1969) (7), Norton and Hansen (1969) (13), Wells et al. (1969) (21), Gilbertson et al. (1970) (5), and Wells et al. (1971) (19). Table IV-1 is representative of this type of data and presents average concentrations of selected chemical parameters measured in direct runoff waste from feed pens and discharge water from collection ponds on a 12,000-head open feedlot in north central Texas (4). The data reported by these

TABLE IV-1

AVERAGE CONCENTRATIONS OF SELECTED CHEMICAL PARAMETERS (Mg/1) (4)

	Direct Runoff	Discharge Water
Biochemical Oxygen Demand	2201	558
Chemical Oxygen Demand	7210	2313
Total Solids	11429	3172
Total Dissolved Solids	5526	1875
Organic Nitrogen	228	64
Total Phosphate	70	38
Ammonia	108	50

authors varied significantly with respect to actual numerical values for most parameters but consistently agreed that runoff from cattle feedlots was extremely concentrated and carried a high pollution potential.

RUNOFF CHARACTERISTICS

Data collected by Wells et al. (19) have shown that the concentration of pollutants in runoff is relatively independent of the type of ration fed. The concentration of runoff is affected greatly by the amount and duration of a runoff event generated by a storm. The first runoff from a lot surface during a storm will have extremely high concentrations of pollutants as shown in Table IV-2.

TABLE IV-2

CONCENTRATIONS OF POLLUTANTS IN RUNOFF FROM CONCRETE LOT RESULTING FROM PRECIPITATION STARTING AT 11:00 P.M. ON AUGUST 24, 1969 (19)

Time of Collection	pH	BOD (mg/l)	COD (mg/l)	NO (mg/l)	NH_3-N (mg/l)	ORG-N (mg/l)	ALKY (mg/l)
11:35 p.m.	6.60	16,800	48,000	625	525	532	2,595
11:58 p.m.	6.80	6,120	20,451	975	526	315	1,955
12:25 a.m.	6.65	7,400	22,032	1,000	485	36	2,000
2:25 a.m.	6.80	9,950	23,316	900	543	285	1,865

Feedlots have received much publicity regarding fish kills caused by feedlot runoff entering a nearby stream. The reason for such kills can easily be accounted for by the very high concentration of the biochemical oxygen demand (BOD) of the runoff, which depletes the dissolved oxygen (DO) in the stream. The situation in the stream is that all oxygen-using life will die when this slug of runoff moves down the stream. At some point in the stream, enough other water may be mixed with the runoff slug to bring the DO to a sufficient life-supporting level. When feedlot runoff enters a non-flowing body of water, the time required to regain a sufficient level of DO may be very long and will depend greatly on biological breakdown of the waste.

Table IV-3 shows the reaction of a stream to a slug of feedlot runoff passing a sampling point in that stream.

TABLE IV-3

FOX CREEK NEAR STRONG CITY, KANSAS, NOVEMBER 1962

WATER QUALITY PARAMETERS (mg/l) (17)

TIME	DO	BOD_5	COD	Cl^-	NH_3
Avg. Dry Weather	8.4	2	29	11	0.06
13 hours	7.2	8	37	19	12.0
20 hours	0.8	90	283	50	5.3
26 hours	5.9	22	63	35	----
46 hours	6.8	5	40	31	0.44
69 hours	4.2	7	43	26	0.02
117 hours	6.2	3	22	25	0.08

Table IV-4 shows strength of feedlot runoff and its effect on a receiving reservoir even though the runoff has been diluted with water 4 to 1. The third line of data in this table shows test results from a sister reservoir that did not receive feedlot runoff.

TABLE IV-4

WATERSHED RESERVOIRS AND FEEDLOT NEAR McKINNEY, TEXAS
WATER QUALITY PARAMETERS (mg/l) (4)

	DO	BOD_5	COD	Cl^-	NH_3
Feedlot Runoff	---	2200.0	7210.0	450.0	108.0
Reservoir Receiving *F.R.	0.0	86.5	81.0	40.5	6.0
Reservoir No. F.R.	7.8	5.0	29.0	7.2	0.548

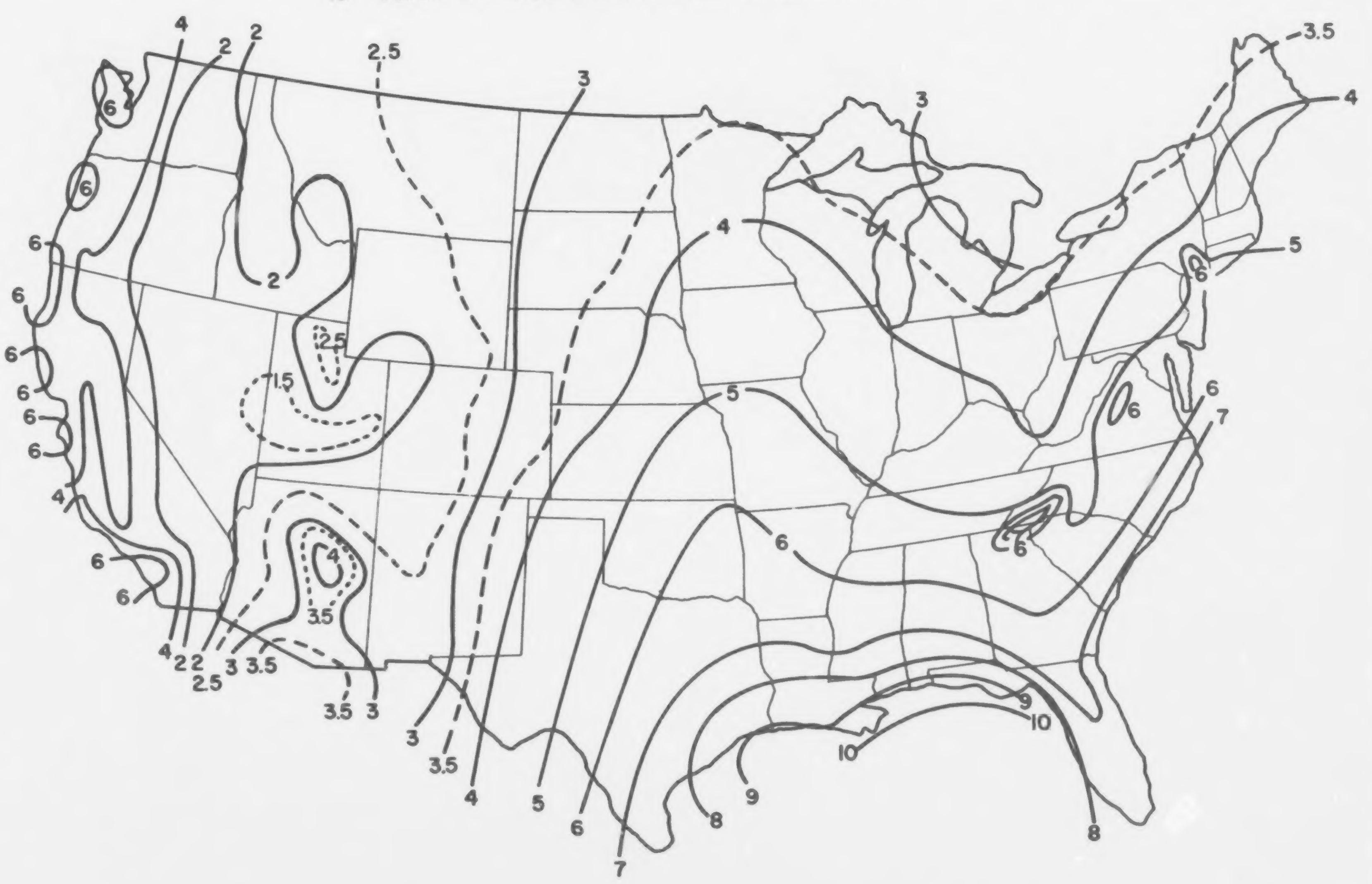
*Dilution, 1 part feedlot runoff to 4 parts impounded storage water.

The amount of solids removed from a feed pen during a runoff event will vary greatly with the intensity of the rain and with the slope of the lot surface. McCalla et al. (10) in Nebraska have suggested that about 1.3 tons of solids will be removed with each acre-inch of runoff. For snowmelt runoff, as much as 7.0 tons per acre-inch can be expected. The volume of a ton of these solids has been determined to be approximately 32 cubic feet.

Volume of Runoff Wastes

The volume of feedlot runoff to be managed can be determined by using the Soil Conservation Service method for estimating the amount of direct runoff from rainfall (14). The procedure is as follows:

1. Determine the drainage area (DA). Ideally, this drainage area should include only the feedlot area with diversion structures installed around the feedlot to divert outside waters.
2. Determine storm rainfall (P). The design storm intensity used may depend primarily upon the state laws and regulations governing the design of the retention structures. The most common design rainfall is the 10-year 24-hour storm shown in Figure IV-1.


10 - YEAR 24 - HOUR RAINFALL (INCHES) (20)
4
2
2
2.5
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6

FIGURE IV-1. 10-YEAR 24-HOUR RAINFALL (INCHES) (20).

3. Determine the runoff (Q) in inches. The runoff can be estimated by the following equation:

$$Q = \frac{(P - 0.352)^2}{P + 1.41} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{EQN (IV-1)}$$

where: Q = inches runoff
P = inches precipitation

This equation is based upon the SCS method of estimating the amount of direct runoff from rainfall for classified condition III, soil group D, land use farmstead. Equation (IV-1) closely matches experimental results found in Nebraska, Kansas, and Colorado. It takes into account approximately 0.4 of an inch of storage on the feedlot surface. For rainfalls over 1/2 inch, a quick rule of thumb, based upon the Nebraska (2) data, is:

$$Q = P \times 0.7 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{EQN (IV-2)}$$

4. Runoff volumes may also be obtained by using the charts presented in Figures IV-2, IV-3, IV-4, and IV-5. As an example of how to use the runoff-rainfall charts for a given location, use the following condition and check the charts for the answer.
   a. Use a 10-year 24-hour design storm.
   b. Select a location near Wichita, Kansas.
   c. Assume a dry, unsurfaced lot.

From Figure IV-1, the design rainfall will be approximately 5.0 inches. Using Figure IV-5, the runoff per acre will be approximately 2.8 inches; however, assume 3.0 inches.

If the feedlot drainage area is known, it is then a simple matter to multiply the acres in the drainage area by the

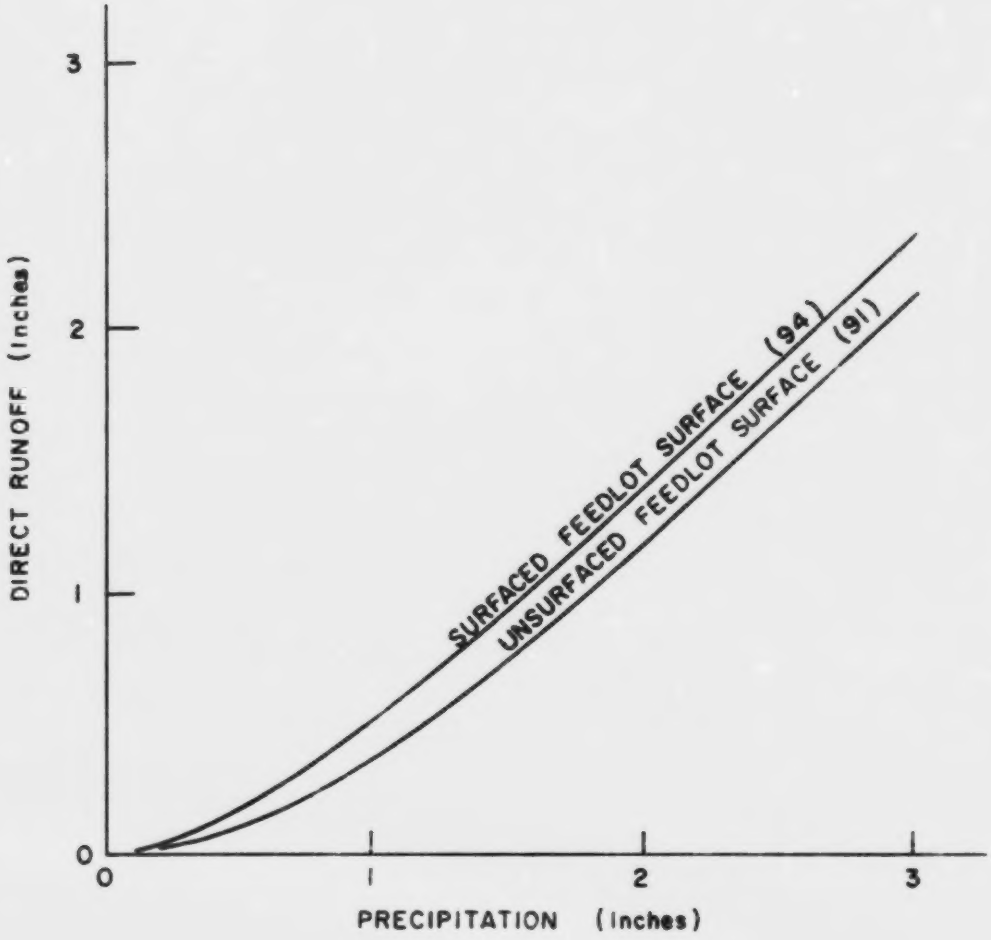


FIGURE IV-2. RELATIONSHIP BETWEEN PRECIPITATION AND RUNOFF FROM CATTLE FEEDLOTS (SOIL COVER COMPLEX NUMBERS 91 & 94). INTERPOLATED FROM BERGSRUD (1).

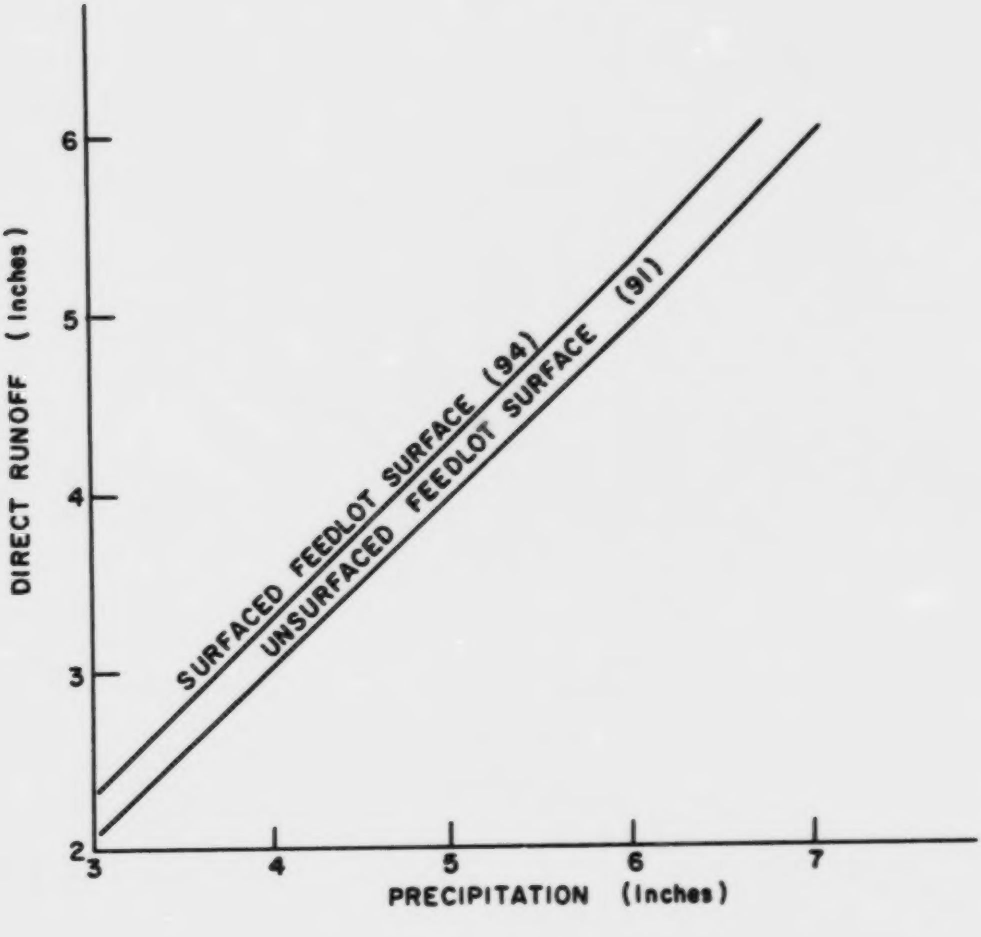


FIGURE IV-3. RELATIONSHIP BETWEEN PRECIPITATION AND RUNOFF FROM CATTLE FEEDLOTS (SOIL COVER COMPLEX NUMBERS 91 & 94). INTERPOLATED FROM BERGSRUD (1).

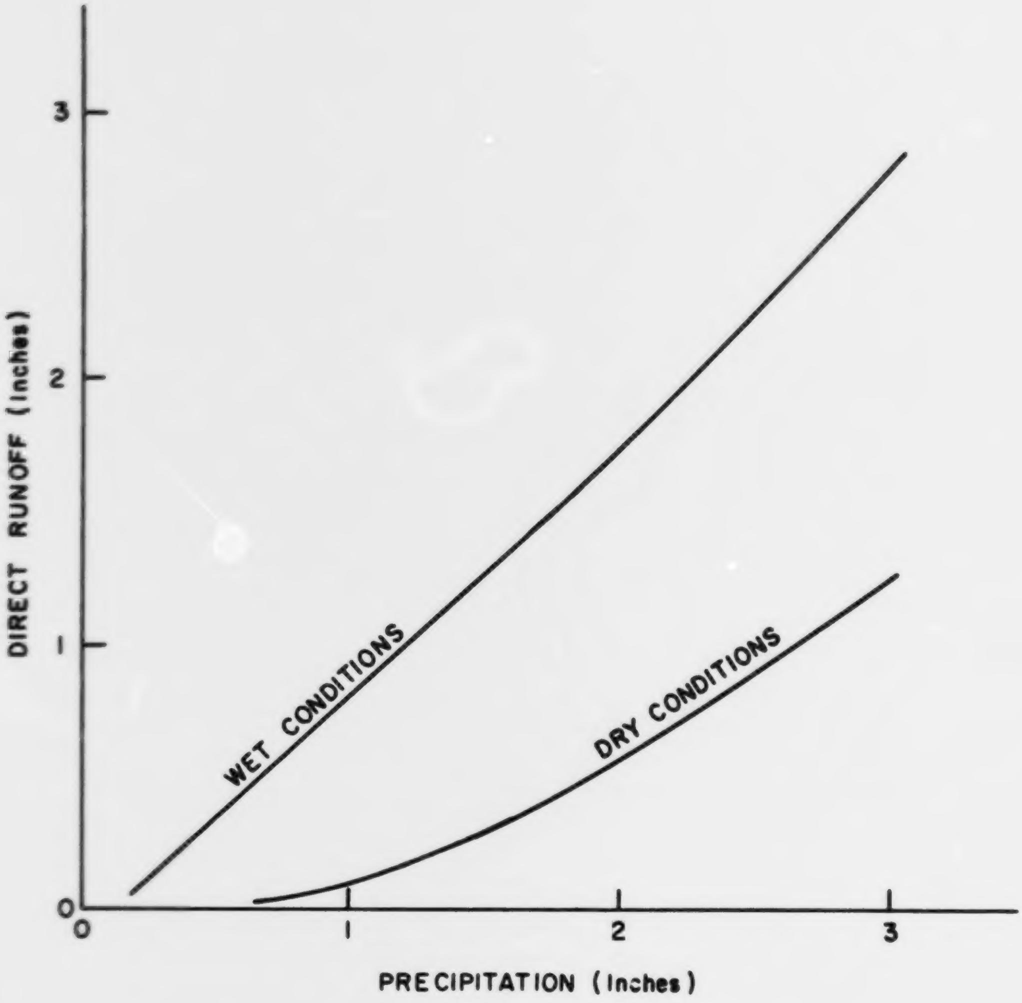


FIGURE IV-4. RELATIONSHIP BETWEEN PRECIPITATION AND RUNOFF FOR WET AND DRY CONDITION ADJUSTMENTS OF SOIL COVER COMPLEX NUMBER 91. INTERPOLATED FROM BERGSRUD (1).

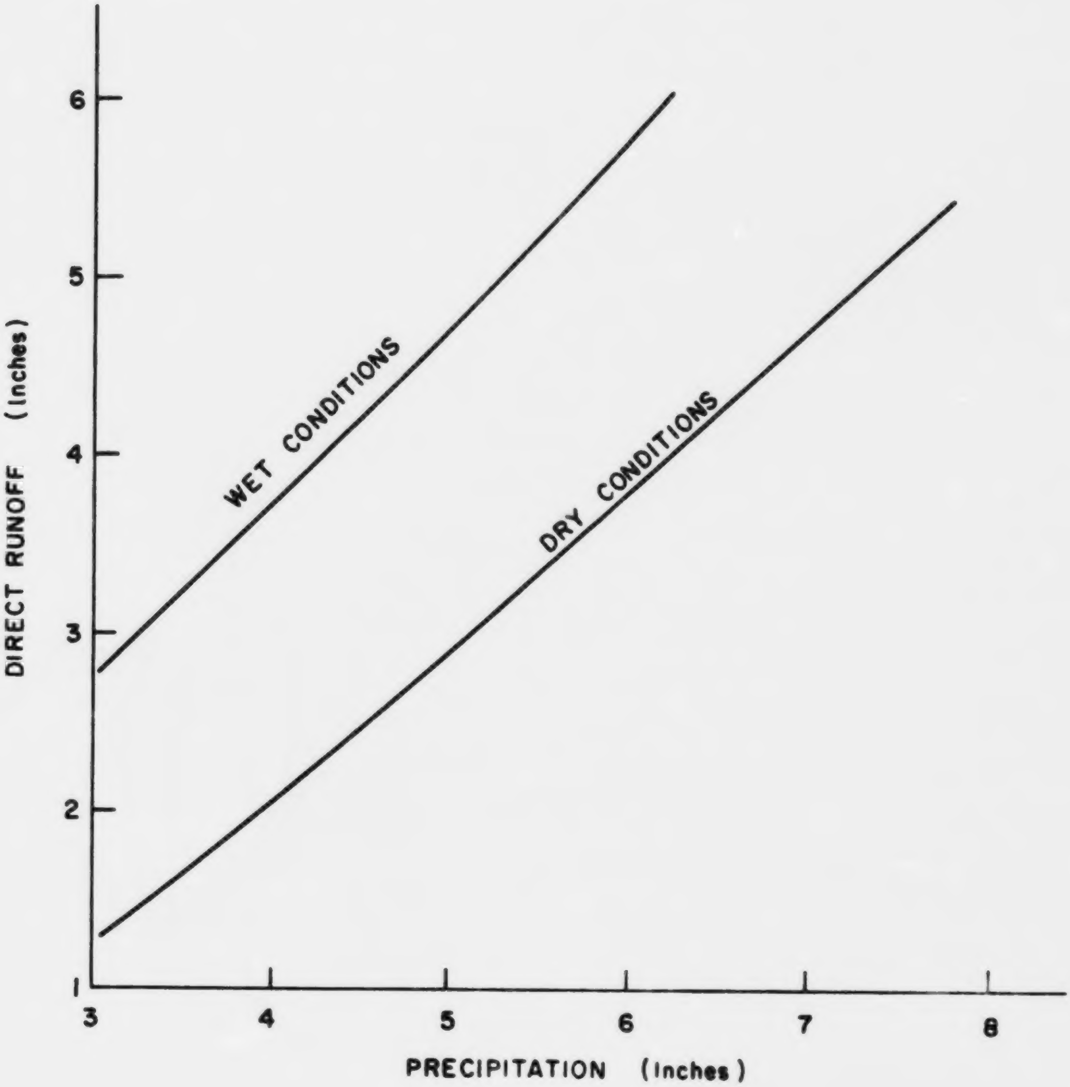


FIGURE IV-5. RELATIONSHIP BETWEEN PRECIPITATION AND RUNOFF FOR WET AND DRY CONDITION ADJUSTMENTS OF SOIL COVER COMPLEX NUMBER 91. INTERPOLATED FROM BERGSRUD (1).

inches of runoff per acre and arrive at the design runoff volume that must be retained. For example:

Assume 100 acres of feedlot drainage
100 acres x 3.0 inches per acre = 300 acre-inches of runoff.

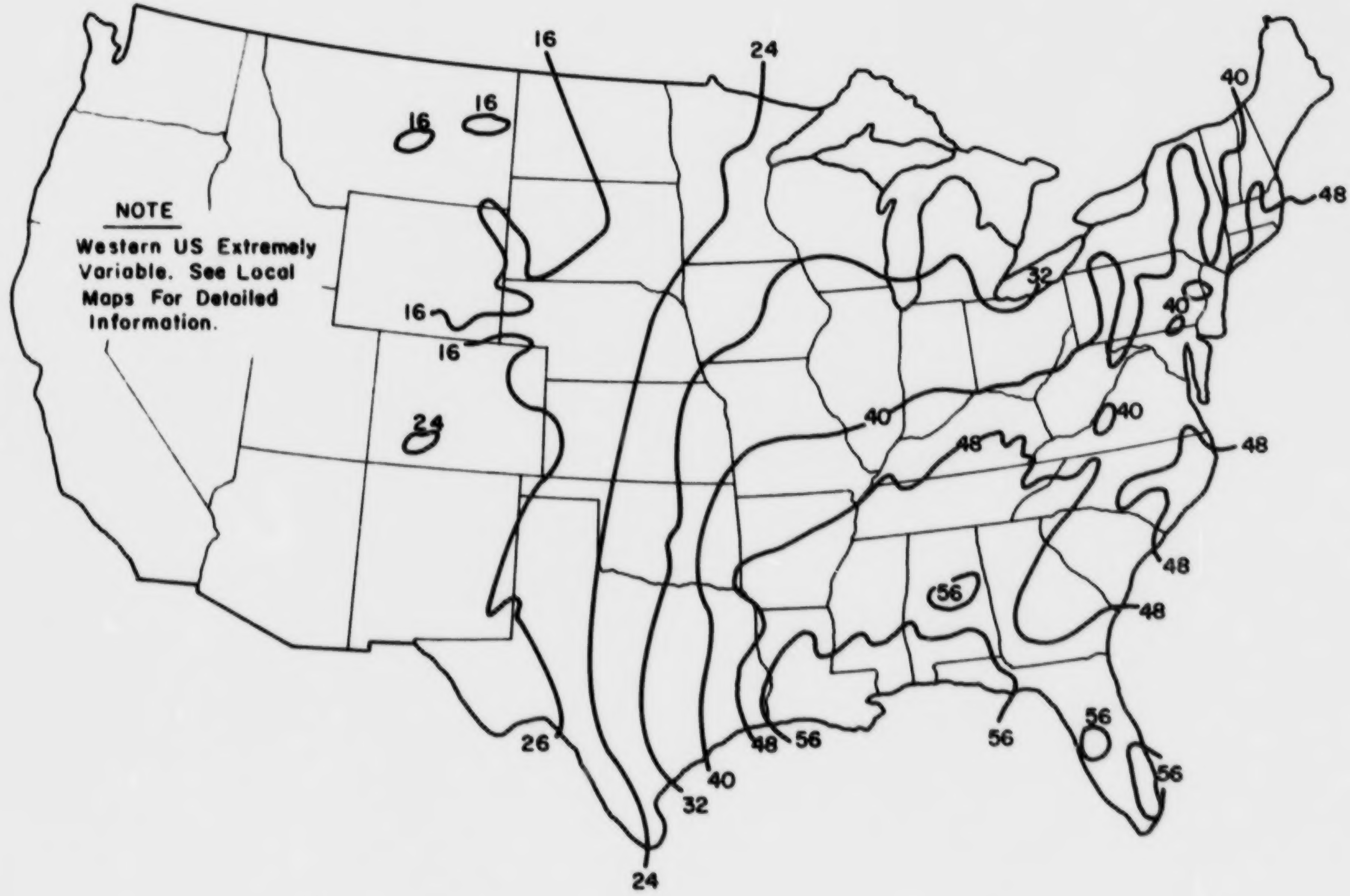
Most runoff control facilities will not be concerned with annual runoff, Figure IV-6, unless storage is needed or required for some portion of the annual runoff.

Annual runoff becomes extremely important if evaporation is to be used as a disposal method and can be calculated by obtaining from the U. S. Weather Bureau rainfall records and applying the runoff-rainfall charts to these storms and totaling the runoff for a given year (see section on evaporation in this section, page IV-23).

TRANSPORTATION OF RUNOFF TO COLLECTION AREA

Feed pen slope is important to insure that runoff will be removed from the pens as quickly as possible to prevent sloppy conditions. The pen surface should have at least 2 to 3 percent slope, and this slope must be maintained during operation of the lot. Feedlot designs should provide drainage channels to insure that the runoff will be transmitted from the pens to the nearest collection ponds.

These drainage channels or transport systems can usually be divided into two types. The first type is used to transport the total runoff, liquid and solid, to the collection areas. This system usually consists of deep, narrow, and steep, fast flowing ditches. The second type is used not only for transport but also for solids removal. This can be accomplished by reducing the velocity of the flow enough to allow a portion of the solids to settle out. An example of this system with removable dams is shown in Figure IV-7. Gilbertson et al. (6) in Nebraska have experimented with this design and found it to be promising. The dams can be porous


16
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NOTE
Western US Extremely Variable. See Local Maps For Detailed Information.
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24

FIGURE IV-6. MEAN ANNUAL PRECIPITATION IN THE UNITED STATES (3).

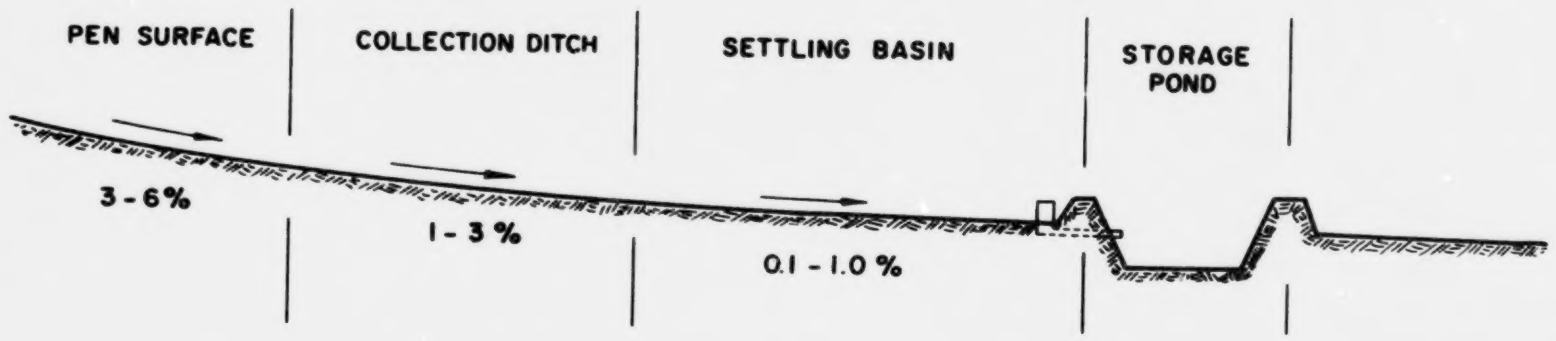

PEN SURFACE
COLLECTION DITCH
SETTLING BASIN
STORAGE POND
3 - 6%
1 - 3 %
0.1 - 1.0 %

FIGURE IV-7. SCHEMATIC ILLUSTRATING SLOPES IN A GRAVITY COLLECTION, SOLID SEPARATION, AND STORAGE SYSTEM.

rock, boards or hardware cloth on frames. It is desirable to build the dams so that they can be easily removed for cleaning of the channel. In areas where rainfall is seasonably light, these drainage channels with dams will usually dry enough to allow solids removal with normal tractors and loaders. If there is a possibility that the drainage channels will remain wet all year, consideration should be given to dragline or track laying equipment for solids removal.

Removal of Solids from Runoff

Research suggests and some states require that solids be removed prior to storage of the runoff and that the removal system be designed as an integral part of the control system. Some states require the minimum volume for solids storage to be 10 percent of the design runoff volume.

If solids are not removed in the drainage channel, then a debris basin must be designed for this purpose. If the solids removal system is planned, removal can be accomplished in an orderly and efficient manner; however, if solids are allowed to deposit on the bottom of a large lagoon or holding area, their removal at some future time may be very difficult without special equipment.

Solid Settling Basin Design

A variety of settling basin designs has been developed. An easily constructed, commonly used design (illustrated in Figure IV-7) consists of a shallow basin bounded on the down slope side by the retention pond dyke. Runoff drains from the pens and/or collection ditch through the settling basin, through a small culvert or standpipe with inlets at multiple levels, and into the storage pond. Thus, the flow of the runoff is interrupted. The interruption creates a short period of retention which causes sedimentation. Figure IV-8 depicts a settling basin which is allowed to dry prior to solids removal.

Gilbertson et al. (6) developed two experimental systems for removing settleable solids from outdoor beef cattle feedlot runoff. One system is

FIGURE IV-8. SETTLING BASIN, DRYING PRIOR TO REMOVAL.

called a batch system and the other a continuous flow system. These systems are illustrated in Figures IV-9 and IV-10.

For the batch system, the components are a primary settling basin and a secondary basin. All runoff from a given storm event is trapped within the primary settling basin and detained to allow the heavier solids to settle to the bottom of the basin. The supernatant is pumped from the primary basin into the secondary basin for longer detention times. The continuous flow system consists of a series of porous dams which reduce the velocity of flow sufficiently to allow the heavier particles to remain in the settling channel while the liquids flow by gravity to a liquid storage pond. The porous dams are constructed of crushed rock and planking, with cracks between the planking.

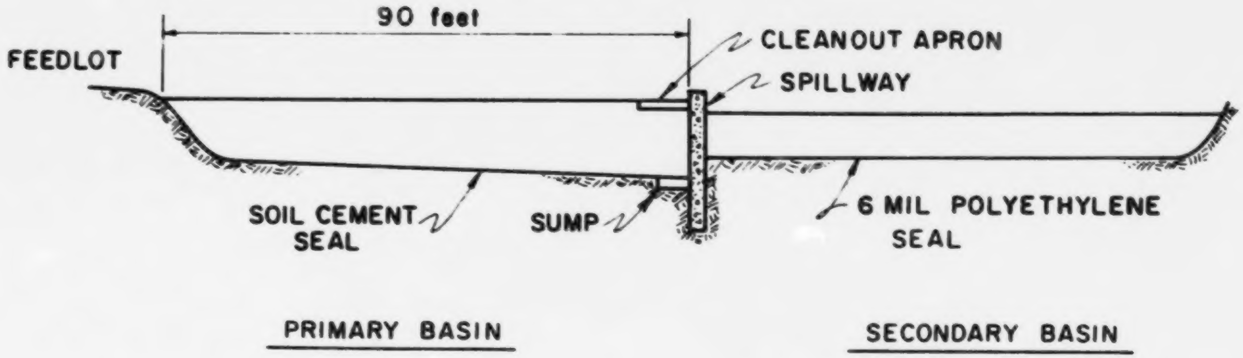

90 feet
FEEDLOT
CLEANOUT APRON
SPILLWAY
SOIL CEMENT SEAL
SUMP
6 MIL POLYETHYLENE SEAL
PRIMARY BASIN
SECONDARY BASIN

FIGURE IV-9. SCHEMATIC OF A BATCH COLLECTION BASIN FOR REMOVING SETTLEABLE SOLIDS IN RUNOFF (6).

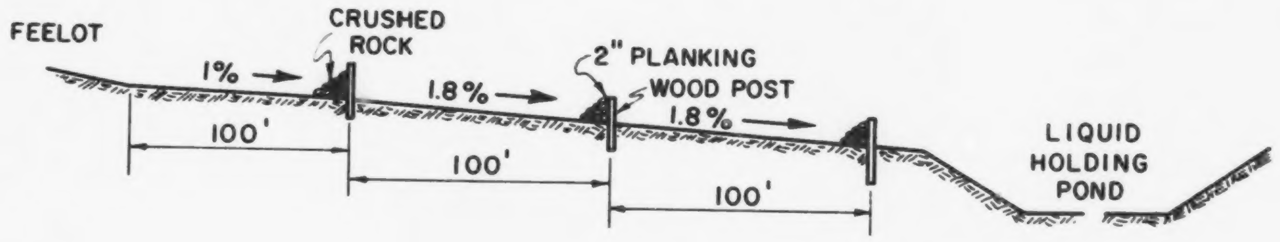

FEELOT
CRUSHED ROCK
1% →
100'
1.8% →
100'
2" PLANKING
WOOD POST
1.8% →
100'
LIQUID HOLDING POND

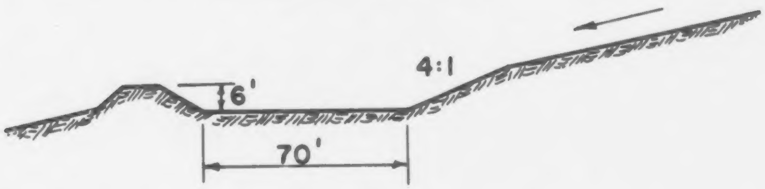
FIGURE IV-10. SCHEMATIC OF THE CONTINUOUS FLOW CONCEPT FOR REMOVING SETTLEABLE SOLIDS IN RUNOFF.

The batch system removes the settleable solids efficiently; however, the system maintenance has serious disadvantages. The primary settling basin must have sufficient capacity to prevent direct overflow to the secondary basin. Also, removing the accumulated solids from the primary settling basin requires specialized equipment; for example, a dragline bucket.

The continuous flow concept is a low maintenance method for removing the settleable solids. A series of three porous dams in the settling channel of the continuous flow system removes about 50 percent of the total solids transported. The first dam removes 80 percent of this total. Front end loaders on tractors are utilized to clean the settling channel. Odors are not detected as readily from the continuous flow system as from the batch system. The settling of solids during the winter months presents problems for both methods.

Broad Basin Terraces. Swanson (18) developed a broad basin terrace concept of runoff control for eastern Nebraska, Figure IV-11. On one lot with a 15 percent slope, a single basin was constructed where the feedlot has been in existence for more than 20 years. The basin was designed to have a storage capacity for 12 inches of runoff from the lot plus one foot of freeboard. This storage would be adequate for the total runoff in a normal year. However, storage was not planned for a long period since the effluent was to be pumped out and distributed on adjacent crop land. The channel width of the broad basin terrace was approximately 70 feet across with a 4 to 1 slope on the feedlot side. The terrace was constructed to a 6-foot height to form the basin. These basins were constructed inside the lots and provided an area to push snow if necessary. Also, there was no problem with weed growth around the basin. Experience has shown that the basins dry out rapidly after drainage. The removal of the solids allows the runoff to be easily disposed on land with conventional irrigation equipment, without having undue problems with nozzle plugging and excessive bearing wear on sprinkler systems.

SINGLE BROAD BASIN TERRACE



MULTIPLE BROAD BASIN TERRACE

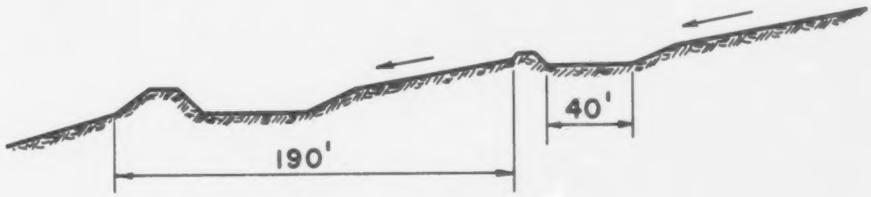


FIGURE IV-11. SCHEMATIC OF BROAD BASIN TERRACES FOR DETAINING RUNOFF FROM FEEDLOTS (18).

The operational design of the debris basin must include a drawdown structure which allows all the water to be removed from the basin, leaving only the solids in the bottom. This can be accomplished many ways, but the simplest is to provide a vertical drawdown pipe for high flows and slot the side walls of this pipe to allow for the effective removal of water from the basin.

Runoff Collection Ponds

The location of a collection pond relative to the feedlot will be dictated by the topography of the land since it is desirable that the runoff be transported to the collection pond by gravity (Figure IV-12). In some cases involving existing feedlots, high volume pumps at low points within the feedlot may be the only means of moving the runoff to collection areas.

Collection ponds usually fall into two categories. One may simply be a pond designed to handle the design storm runoff and to retain this runoff a very short time, until it can be transferred to other areas for disposal. The second category is comprised of ponds designed to retain the runoff until disposal can be accomplished. This type of pond usually requires additional storage volume for management.

The design of the collection pond should be based on the volume of runoff generated by the design rainfall, plus any excess storage which might be needed for management of the disposal system for these wastes. The usual management volume would be at least 50 percent of the design storm runoff; however, some disposal systems may require even more management volume. It is mandatory that at least 1.5 feet of freeboard be provided above the maximum stored water elevation in these structures. This extra depth will insure that wave action will not damage the earthen embankment and cause a failure of the structure. If such a failure did occur, it might be ruled by the court as a case of failure to maintain

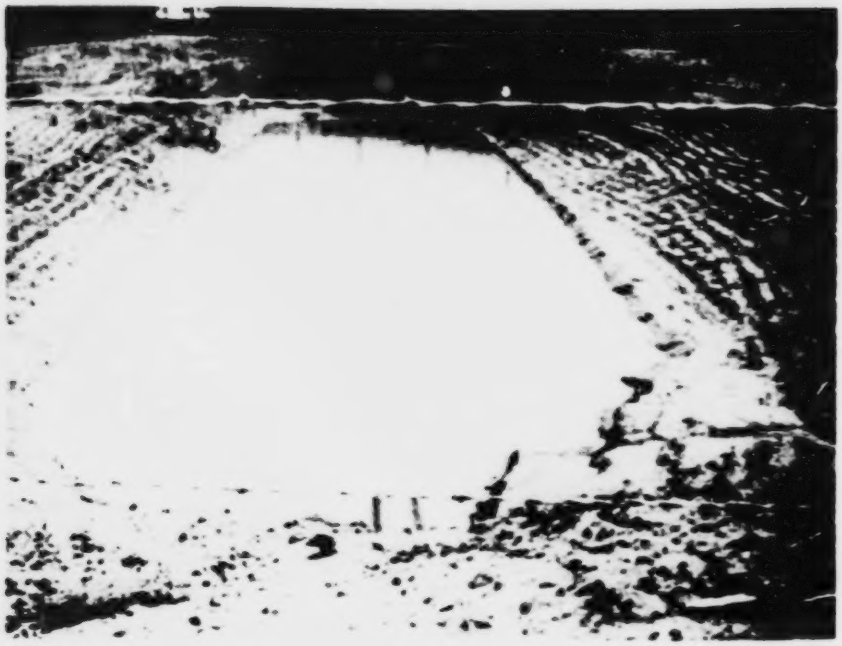


FIGURE IV-12. COLLECTION POND. THIS POND HAS A GRAVITY INLET IN FOREGROUND. REMOVAL OF LIQUID IS ACCOMPLISHED BY A PORTABLE PUMP AND IRRIGATION SYSTEM.

the structure, and the operator could be judged negligent and be held responsible for all damage caused by such a failure.

If the feedlot is located on land which has topography suited for small dams and ponds, the runoff might be collected and stored in a structure of this type, which would be less expensive storage than excavating the entire storage volume. However, if dammed gullies are to be used as runoff storage area, it is desirable to divert the normal gully flow around the runoff storage site. If this diversion is not installed, the volume of polluted water to be managed can be greatly increased and, in most cases, the increase is undesirable.

The physical slope of these ponds is not especially important with the exception of the side slopes which must be flat enough to allow an animal or person to climb out of the water. This usually requires a slope of 3 to 1 (3 feet horizontal to 1 foot vertical). In many areas it may be desirable, if not mandatory, to fence all ponds to keep both animals and humans from getting close to the water.

Site Selection for Debris Basins and Collection Ponds. The site for these structures should be very carefully investigated to insure that the structure will not intercept fractured rock or a water table. A detailed discussion of site selection is presented in Section III. It is important, and in some states mandatory, that seepage from any lagoon or pond be eliminated. Several states require percolation tests to be submitted along with plans for the holding structures. Some soils need to be treated before the lagoon or pond is used. Treatment may consist of over excavation and replacement with compacted earth as a liner. Bentonite may be mixed with the soil and compacted for such a seal, or a plastic membrane may be installed.

DISPOSAL AND/OR TREATMENT SYSTEMS

Land disposal of runoff wastes is the most practical means of handling the wastes since treatment of the high strength runoff wastes is, in most cases, impractical from not only a technical standpoint but also from an economical standpoint.

There are two experimental treatment systems which may prove the exception to this rule; however, both need further refinement before they are ready for widespread use. Both of these systems will be described briefly, one at the end of this section and the other in Section VI.

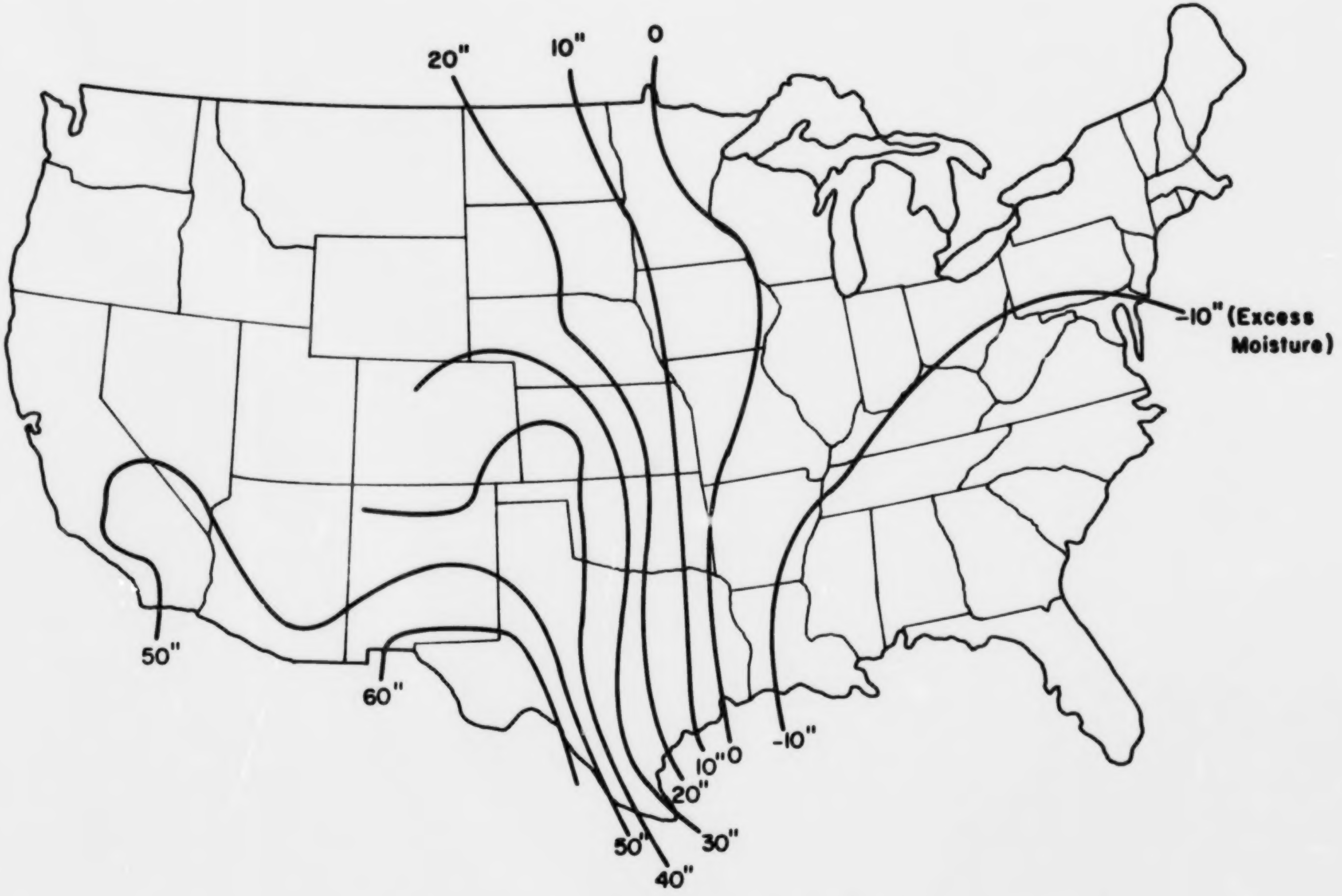
The most common treatment systems employed for animal wastes are anaerobic lagoons, anaerobic digestion, oxidation ditches, aerated lagoons and combinations of these systems. These treatment systems have been discussed at length in Section VI and, if they are to be considered for use with feedlot runoff, it is suggested that further study be directed to Section VI.

The major drawback to these systems for runoff wastes is that runoff wastes occur as slugs, not as a continuous flow, and most of these systems do not respond to slug loading. Also, the anaerobic systems are noted for their malodorous gases, which are very objectionable. Mechanically aerated systems will have a high power requirement to provide the necessary oxygen to keep the system aerobic. If the odors and power requirements can be overcome, the effluent from these systems have enough strength to be unsuitable for discharge into any watercourse and must still be disposed by land application.

Evaporation Disposal

In areas of the United States where the moisture deficit, evaporation minus rainfall, (Figure IV-13) exceeds 30 inches annually, evaporation of runoff wastes may prove to be the most economical method of disposal. Evaporation lagoons must be sized to provide the necessary surface area to evaporate the total annual runoff volume plus the precipitation that would fall on the lagoon. The system should be designed to provide additional capacity for wet years. This could be accomplished by the use of additional surface area or by using an irrigation system as a back-up disposal system.

The design of an evaporation system will require extensive knowledge of storm patterns in order to provide the necessary surface area and storage volume for wet seasons of the year. Monthly evaporation rates in conjunction with monthly runoff volumes will also be necessary for the final sizing of the system. The following example was based on conditions which exist in central Kansas. The rainfall period was selected to be the fourth wettest year in the last 50 years.



20"
10"
0
-10" (Excess Moisture)
50"
60"
-10"
10" 0
20"
30"
50"
40"

FIGURE IV-13. LINES OF MOISTURE DEFICIT FOR THE UNITED STATES (3).

The rainfall and evaporation data, Table IV-5, were obtained from U.S. Weather Bureau files, and the runoff was calculated by the use of the runoff curves shown in Figures IV-2, IV-3, IV-4, and IV-5. Each individual storm was considered, and the totals constituted the monthly values shown in Table IV-5. The data in Table IV-5 can now be used to calculate the area of land needed to evaporate the runoff from 10 acres of feedlot.

TABLE IV-5

CLIMATIC DATA FOR EXAMPLE

Month	Rainfall inch	Runoff inch	Total Evaporation inch
Oct.	4.28	3.00	6.2
Nov.	1.86	0.58	0.2
Dec.	1.30	0.56	0.0
Jan.	0.19	0.0	0.0
Feb.	0.35	0.10	0.0
Mar.	1.00	0.55	0.0
April	2.26	0.80	7.2
May	4.19	1.62	8.6
June	2.76	1.00	9.3
July	3.59	1.62	9.0
Aug.	5.25	3.13	10.3
Sept.	3.11	1.37	7.6
Total	30.14	14.33	58.2

The process is somewhat trial and error; therefore, after several tries, Table IV-6 for 5 acres of evaporation area was selected for presentation here.

TABLE IV-6

VOLUME - STAGE OF EVAPORATION POND FOR 10 ACRE FEEDLOT - 5 ACRE POND

Month	Inflow Rainfall + Lot Runoff (Acre-inch)[1]	Evaporation (Acre-inch)[2]	Storage Volume (Acre-inch)[3]	Stage of Pond (inches)[4]
Oct.	51.4	31.0	20.4	4.1
Nov.	15.1	0.0	35.5	7.1
Dec.	12.1	0.0	47.6	9.5
Jan.	1.0	0.0	48.6	9.7
Feb.	1.8	0.0	50.4	10.1
Mar.	10.5	0.0	60.9	12.0
April	19.3	36.0	44.2	8.0
May	37.2	43.0	38.4	7.7
June	25.8	46.5	17.7	3.5
July	34.2	45.0	6.9	1.4
Aug.	57.6	51.5	13.0	2.6
Sept.	29.3	38.0	4.3	0.1

[1] Rainfall x 5 + Runoff x 10 = Inflow (Acre-inch)

[2] Evaporation x 5 = Evaporation (Acre-inch)

[3] Inflow (Acre-inch) - Evaporation (Acre-inch) = Storage Volume (Acre-inch) at end of month.

[4] Storage Volume (Acre-inch)/5 = Stage of Pond (Inches)

This example, Table IV-6, indicates that the pond would not be dry during the year; however, some evaporation will occur in the winter months even though the data indicates zero evaporation.

Evaporation systems usually require large land areas, and these areas are not productive once they have been committed to this type of system. Land for this system must be naturally flat or be shaped to provide ponds that are shallow, uniform in depth, and have large surface areas. If the land is sloping, it will be necessary to install grade separation structures to insure a uniform shallow depth and provide a maximum surface area for evaporation.

Irrigation Disposal

The disposal of feedlot runoff by irrigation is the most common disposal method used by feedlot operators. This method is usually divided into two specific systems. The first and most common system is the disposal of the liquid without regard for crop utilization of the nutrients in the waste. The second system is applying the waste to cropland at such a rate as to reclaim the majority of the nutrients in the production of a crop.

The first system is simply disposal of runoff waste to grassland without regard for nutrient loading. The only criteria is an application rate that does not produce runoff. This system is very workable and reasonable in situations where the feedlot is not involved in farming and has access to large acreages of pasture. Problems develop when not enough land area is available and the application amounts become excessive, resulting in reversion from a grass regime to a weed regime and loss of pasture value.

The nutrient use system requires correlation of waste application rates to the nutrient needs of the crop and content of the waste. In most cases, the factor controlling the amount of runoff wastes that may be applied as irrigation water will be the total salt content of the liquid rather than the nutrient needs of the crop. Studies conducted by Manges et al. (8), Kansas State University, have shown an increase in the electrical conductivity of the soil extract, along with a reduction in yield at total applications of 8 inches per year or more. Data in Table IV-7 give an indication of the yield reductions from two annual applications of runoff and the change in electrical conductivity of the soil for the same period.

The most important factor in water use is the daily or monthly use of the crop. Table IV-8 indicates the daily water use and the total consumptive use of crops grown in Kansas. From this table, one can determine the total water used each month and subtract rainfall from this to predict how much water can be disposed of in any month. The peak use of most crops is approximately 0.3 inches per day. An irrigation system should be able to deliver this amount of water; however, it should be remembered that peak use is a function of evapotranspiration rate and must be determined for each area of climate. The data given here are from Kansas and would not apply in many areas of the United States. However, similar data can be obtained for other areas and the calculations made for the specific area in question. Other examples of peak use rates are given in Table IV-9.

The selection of equipment for irrigation disposal (Figures IV-14 and IV-15) will depend upon the total use of the equipment, type of topography to be irrigated, the type of crop, and the available labor for the operation. If the system is to be used for irrigation of a crop with both fresh water and runoff water, the system will be designed for total irrigation of the crop and will only be modified to utilize the runoff water. If, however, the system is merely for disposal of runoff waste, it may be sized and operated differently from the previous set of conditions. Tables IV-10 and IV-11 give some insight to the ability of several systems to remove a given volume of runoff during a certain time period and also compare the various systems.

Usually self-propelled sprinkler systems are preferred because of a low labor requirement; however, their application rates are normally high and produce runoff on tight soils. If a system is selected to utilize the runoff wastes as a portion of the water required for an irrigated crop, considerable storage must be provided to manage application of the runoff water. This is necessary to allow for both the scheduling of

TABLE IV-7

ELECTRICAL CONDUCTIVITY OF SOIL SATURATION EXTRACT AND YIELD RESPONSE OF CORN AS AFFECTED BY APPLICATION OF FEEDLOT RUNOFF (8)

Treatment Inches of Applied Runoff	Electrical Conductivity[1] Millimhos/cm (soil extract)	Forage Yield[2] Tons/Acre 1970	1971
0	0.51	18.7	14.8
2	0.59	20.3	19.8
4	0.82	21.9	22.4
8	0.87	23.7	19.0
16	1.28	26.7	17.2

[1] Average of four replications

[2] Yield corrected to 70% moisture
Average of four replications

TABLE IV-8

DAILY AND TOTAL CONSUMPTIVE USE OF WATER BY CROPS (16)

	Daily Water Use (Inches Per Day)				Consumptive Use Inches
Crops	June	July	Aug.	Sept.	
Alfalfa	.30	.32	.30	.24	29-37
Corn	.07	.31	.33	.15	24-27
Sorghums	.07	.24	.29	.10	20-23
Pasture	.26	.29	.27	.21	25-32
Wheat (winter use)	.26	.00	.00	.00	13-17

TABLE IV-9

PEAK MOISTURE USE FOR COMMON IRRIGATED CROPS AND OPTIMUM YIELDS (8)

	Cool Climate		Moderate Climate		Hot Climate		Desert Climate	
CROP	Inches per day[1]	GPM per acre[2]	Inches per day	GPM per acre	Inches per day	GPM per acre	Inches per day	GPM per acre
Alfalfa	.20	3.8	.25	4.7	.30	5.7	.35	6.6
Cotton	.20	3.8	.25	4.7	.30	5.7	.35	6.6
Pasture	.20	3.8	.25	4.7	.30	5.7	.35	6.6
Grain	.15	2.8	.20	3.8	.22	4.2	.30	5.7
Potatoes	.14	2.8	.20	3.8	.25	4.7	.30	5.7
Beets	.20	3.8	.25	4.7	.30	5.7	.35	6.6
Orchards and Groves	.20	3.8	.25	4.7	.30	5.7	.35	6.6
Orchards and Groves w/Cover	.25	4.7	.28	5.2	.35	6.6	.38	7.2

[1] Acre inches per acre per day

[2] Continuous flow required per acre at 100% irrigation efficiency. Divide this value by estimated irrigation efficiency.

TABLE IV-10

ANIMAL WASTE DISPOSAL BY TANKWAGON OR PIPING SYSTEM (15)

Number of Days (10 hours/day) Required to Dispose of a Given Quantity of Liquid Wastes

Gallons Per Minute	Acre-Inch Per Hour	Acre-Inches of Waste							
		6	12	24	36	48	60	120	240
25	0.05	12.0	24.0	48.0					
50	0.11	5.5	10.9	21.8	32.8	43.6	54.6		
100	0.22	2.7	5.5	10.9	16.4	21.8	27.3	54.5	
200	0.44	1.4	2.7	5.5	8.2	10.9	13.6	27.3	54.5
300	0.66		1.8	3.6	5.5	7.3	9.1	18.2	36.4
400	0.88			2.7	4.0	5.5	6.8	13.6	27.4
500	1.10			2.2	3.2	4.4	5.5	10.9	21.8
600	1.32			1.8	2.6	3.6	4.6	9.1	18.1
800	1.77				2.0	2.7	3.4	6.8	13.6
1000	2.21					2.2	2.7	5.4	10.8

UNITS--

1 acre-inch = 27,154 gallons = 3,621 cu. ft.
1 acre-foot = 12 acre-inches = 325,848 gallons = 43,560 cu. ft.
1 acre-inch/hour = 450 gallons/minute = 1 cubic foot/second

TABLE IV-11

WASTE DISPOSAL SYSTEM SELECTION CHART (15)

	Type of System										
	Tank Wagon	Sprinkler								Gravity	
Factor Considered	Honey Wagon	Hand-Carry Sprinkler	Traveling Gun	Towline	Manure Gun	Solid Set	Side Roll	Boom	Center Pivot	Gated Pipe	Open Ditch
Soil Type	Suitable for use on soils with a wide range of intake rates								Moderate to high intake soils	Soils with moderate to low intake rates	
Surface Topography	Adaptable to a wide range of surface topography						Limited to moderately undulating topography		Wide range	Limited to moderate to flat slopes	
Labor Required	Very High on large operations	High	Low	Moderately low	High on large operations	Very low	Moderate		Very low	High	Very high
Management required 1)	Low	Moderately Low			Moderately Low					High	Very high
Flexibility for Expansion	Inflexible 3)	Moderate	Inflexible 3)	Moderate		Inflexible 3)	Moderate	Inflexible 3)	Inflexible 3)	Very flexible	
Initial Investment	Low to Moderate		Moderate	Low to Moderate		Highest	Low to Moderate		High	Low to Moderate	Lowest
Operating Costs 2)	Moderate to High		High	Moderate to High						Low	
Crop Suitability	All except tall growing crops	All	All with Adaptations				All except tall growing crops	All		All	
Size of Operation	Small to Medium Size		All Sizes		Small to medium size		All Sizes		Large	All sizes, depends on topography	
Type of Effluent	Liquids to semi liquid slurries	Liquids only	Liquids to semi-liquid slurries	Liquids only	Liquids to semi liquid slurries		Liquids only		Well filtered liquids	Liquids only	

Note: 1) Management refers to the skill required, or the ability to set the system and go off and leave it.
2) Operating costs are a small factor in selecting a waste disposal system.
3) Of course, another system may be purchased.

FIGURE IV-14. SELF-PROPELLED IRRIGATION SYSTEM FOR WASTEWATER DISPOSAL.

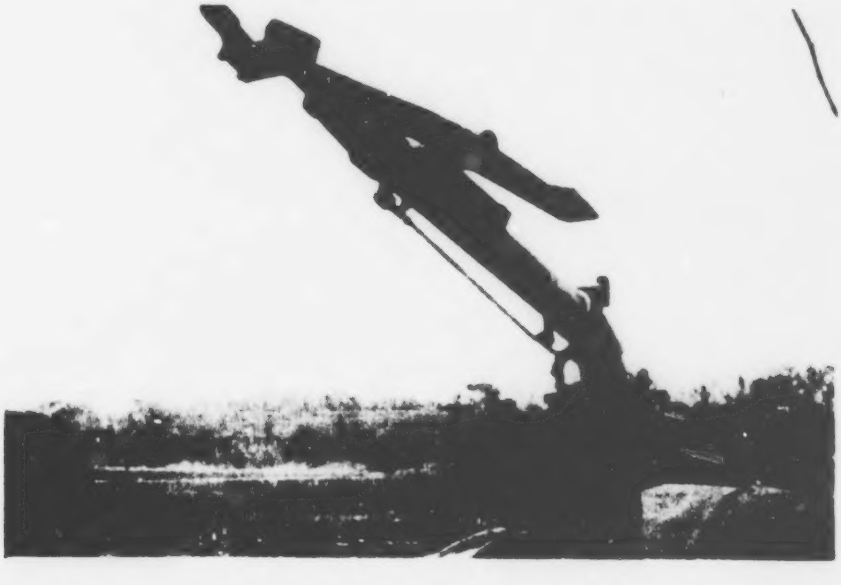


FIGURE IV-15. BIG GUN NOZZLE USED ON SOME SELF-PROPELLED IRRIGATION SYSTEMS.

disposal of the runoff and production of the crop. Spring and fall runoff events may have to be stored to allow planting and harvesting of the irrigated crop. This extra storage volume may equal or exceed the design storage volume.

In order to increase the expected life of irrigation equipment used for runoff disposal, it is desirable to have enough fresh water to thoroughly flush the system after each time it is operated. This practice will reduce the amount of corrosion which might occur from the runoff waste remaining in the system.

Experimental Treatment System

Spray Runoff Treatment. Spray runoff is a technique which has been used successfully to treat cannery wastes, producing effluents of sufficient quality for discharge to the environment. The results obtained by using this treatment method on cannery wastes have shown a potential for treatment of feedlot wastes, especially rainfall runoff from feed pens and manure slurries. Preliminary results obtained from pilot- and full-scale feedlot studies have been most encouraging. Some chemical reductions measured from samples collected from an experimental full-scale spray runoff system operating on a 12,000-head capacity feedlot near McKinney, Texas, are presented in Table IV-12. The system required a 37 acre-foot storage pond and 8 acres of grass treatment area for the 50-acre feedlot.

The system basically is a spray irrigation system with a grass-covered receiving area leveled and sloped so that the runoff flows evenly over the surface at a predetermined rate. A cross-section view of the system is shown in Figure IV-16. The treatment is biological reduction accomplished by a high population of microbes which occur on the wet surface of the grass and soil particles. Thus, to maintain optimum efficiency from the system, a supply of runoff water was maintained, and the runoff water was applied to the treatment area daily or every other day to prevent the area from drying out and killing the population of microbes in the system.

TABLE IV-12

DECREASES OF CONCENTRATIONS OF SOLIDS, OXYGEN DEMAND, AND NUTRIENTS RESULTING FROM SPRAY RUNOFF TREATMENT OF RUNOFF-CARRIED WASTES FROM A 12,000-HEAD NORTH CENTRAL TEXAS BEEF FEEDLOT (4)

Parameter	Runoff Collection Pond (mg/l)	Holding Lagoon mg/l	Treated Discharge mg/l	Percent Total Reduction
Total Suspended Solids	195.0	125.0	12.0	94
Chemical Oxygen Demand	430.0	370.0	125.0	71
Biochemical Oxygen Demand	63.0	28.0	5.0	80
Total Phosphate	13.5	4.1	0.5	96
Total Nitrogen	27.[illegible]	16.3	5.4	81

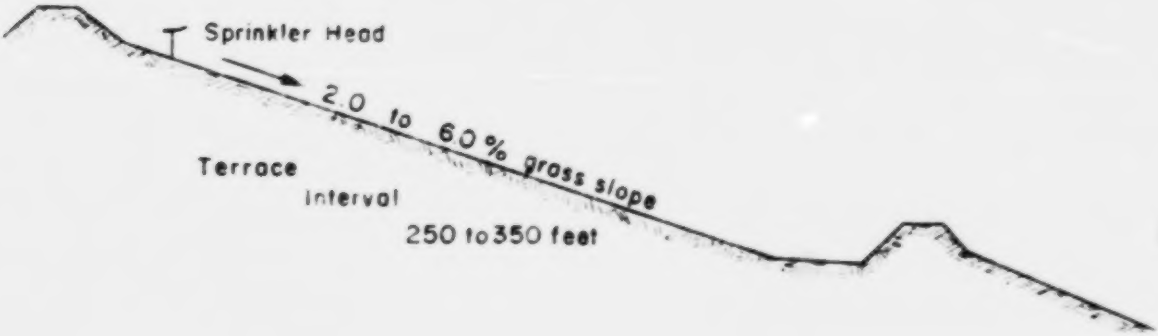

Sprinkler Head
2.0 to 6.0 % grass slope
Terrace
interval
250 to 350 feet

FIGURE IV-16 SCHEMATIC OF A SPRAY RUNOFF TREATMENT SYSTEM

REFERENCES

1. Bergsrud, F. G., Master Report, Kansas State University (1968).

2. Butchbaker, A. F., J. E. Garton, G. W. A. Mahoney, and M. D. Paine, "Evaluation of Beef Cattle Feedlot Waste Management Alternatives," Environmental Protection Agency, Water Pollution Control Research Report 13040FXG (1971).

3. Chow, V. T., Handbook of Applied Hydrology, McGraw-Hill, New York (1964).

4. Duffer, W. R. and R. D. Kreis, "Effects of Feedlot Runoff on the Water Quality of a Small Impoundment," Environmental Protection Agency, Water Pollution Control Research Series, Report No. 16080GGP07/71 (1971).

5. Gilbertson, C. B., T. M. McCalla, J. R. Ellis, O. E. Cross, and W. R. Woods, "The Effect of Animal Density and Surface Slope on Characteristics of Runoff, Solid Wastes and Nitrate Movement on Unpaved Beef Feedlots," Bulletin SB 508, Agricultural Experiment Station, University of Nebraska, Lincoln (1970).

6. Gilbertson, C. B., T. M. McCalla, J. R. Ellis, and W. R. Woods, "Methods of Removing Settleable Solids from Outdoor Beef Cattle Feedlot Runoff," A.S.A.E. Paper No. 70-420, American Society of Agricultural Engineers (July 1970).

7. Grub, W., R. C. Albin, D. M. Wells, and R. Z. Wheaton, "The Effect of Feed, Design, and Management on the Control of Pollution from Beef Cattle Feedlots," Animal Waste Management, Cornell University Conference, pp. 217-224, Syracuse, New York (January 13-15, 1969).

8. Kansas State University, "Demonstration and Development of Ultimate Disposal of Cattle Feedlot Wastes," Interim Report, Project Number 13040DAT, Environmental Protection Agency (1971).

9. Loehr, R. C., "Treatment of Waste from Beef Cattle Feedlots--Field Results," Animal Waste Management Conference, Cornell University, New York State College of Agriculture, Ithaca, New York, p. 225 (1969).

10. McCalla, T. M., L. R. Frederick, and G. L. Palmer, Manure Decomposition and Fate of Breakdown in Soil, published as Paper No. 2742, Journal Series, Nebraska Agricultural Experiment Station, University of Nebraska, Lincoln (1970).

11. Miner, J. R., R. I. Lipper, L. R. Fina, and J. W. Funk, "Cattle Feedlot Runoff and Its Nature and Variation," Journal of Water Pollution Control Federation, Vol. 38, p. 1582, Washington, D.C. (1966).

12. Miner, J. R., R. I. Lipper, and L. E. Erickson, "Modeling Feedlot Runoff Pollution," Transactions of the American Society of Agricultural Engineers, Vol. 10, p. 597 (1967).

13. Norton, T. E., and R. W. Hanson, "Cattle Feedlot Water Quality Hydrology," Animal Waste Management, Cornell University Conference, pp. 202-216, Syracuse, New York (January 13-15, 1969).

14. Oklahoma Design Manual for Small Structures, SCS, USDA, Stillwater, Oklahoma (1969).

15. Peterson, Mark, "The Missouri Irrigation and Land Forming Newsletter," Cooperative Extension Service, University of Missouri, Vol. 1, No. 4 (August, 1971).

16. Shuyler, L. R., "Design for Feedlot Waste Management--Using Feedlot Waste," Presented at Continuing Education Seminar, Kansas Engineering Society, Topeka, Kansas (January 23, 1969).

17. Smith, S. M., and J. R. Miner, "Stream Pollution from Feedlot Runoff," Trans. 14th Annual Conference on Sanitary Engineering, pp. 18-25, University of Kansas (1964).

18. Swanson, N. P., "Broad Basin Terrace Concept of Runoff Control." Paper presented at Midwestern Animal Waste Management Conference National Livestock Feeders Association (November 10-11, 1970).

19. Texas Tech University, "Characteristics of Wastes from Southwestern Cattle Feedlots," Report 13040DEM07/70, Environmental Protection Agency (1970).

20. U.S. Department of Commerce Weather Bureau, "Rainfall Frequency Atlas of the United States," Technical Paper 40, Washington, D. C. (1963).

21. Wells, D. M., E. A. Coleman, W. Grub, R. C. Albin, and G. F. Meenaghan, "Cattle Feedlot Pollution Study," Interim Report No. 1 to the Texas Water Quality Board, Water Resources Center Publication No. 69-7, Texas Tech University, Lubbock, Texas (1969).

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SOLID WASTES CONTROL

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SECTION V

SOLID WASTES CONTROL

NATIONAL PROBLEM

Agriculture is the largest single source of solid wastes in the United States and animal wastes are classified as solid wastes. The Council on Environmental Quality (CEQ), using data from USDA, estimates that in 1969, 4.34 billion tons of solid wastes were produced in the United States (15). Agricultural wastes amounted to 2.28 billion tons of the total. Animal wastes (manure) are estimated at about 1.85 billion tons per year or about 43 percent of the nation's total production of solid wastes.

The beef cattle segment of the industry produces, it is estimated, about 600 million tons annually; thus, 30 percent of all animal wastes are from beef cattle. It should be pointed out that this figure includes all beef animals and not just those in feedlots.

Not only is the total tonnage of manure produced important to the cattle feedlot operator, but also the physical and chemical properties and characteristics of the manure that must be collected, handled, and disposed of from the feedlot.

CHARACTERISTICS OF MANURE

The manure as it is defecated by the animals in the feedlot is characterized by the constituents as approximated in Table V-1. These constituents are significant since 20 to 30 percent of the organic matter is readily decomposed by microorganisms that use oxygen. When the components of manure are permitted to enter a stream, the combination of oxygen depletion and toxic concentrations of ammonia will result in fish kills. The dry mineral matter is largely soluble salts so runoff can be high in salt content and very heavy applications of manure on land can accentuate a salt (salinity) problem. In some areas, feeders add up to

TABLE V-I

SOME CONSTITUENTS OF WASTE FROM A 1,000 POUND BOVINE ON A DAILY AND FEEDING PERIOD BASIS (16).

	Per day	140 days
	Lbs.	Lbs.
Wet manure & urine	64.0	8,960.0
Dry mineral matter	2.1	294.0
Dry organic matter	8.2	1,148.0
Water	53.7	7,518.0
Total nitrogen	0.38	55.0
Total phosphorus	0.048	6.7
Total potassium	0.2	36.4
BOD	1.28	179.2
COD	10.5	1,470.0

1 percent salt to the ration to control urinary calculi--a practice that increases the amount of salt in the waste. The additive is predominately sodium chloride and the related soil problem is caused by the sodium ion, which decreases the water intake rates of fine-textured soils receiving heavy applications of such (saline) manure.

Assuming that 75 percent of the mineral matter on one acre of feedlot pens is soluble in water and that it runs off in an acre foot of water, the salt concentration in the runoff water approximates 8,000 ppm. This water must be diluted prior to soil application from an electrical conductivity of 12 mmhos/cm. (a measure of salinity) with 47 acre-feet of pure water to achieve a conductivity of 0.25 mmhos/cm., the upper limit of total salt content for a class 1 irrigation water (12). These calculations do not consider the sodium hazard of the water, which would be low for animals fed a normal ration but high for those fed a high salt ration (16).

Waste Amount vs. Ration

The total amount of manure produced and, to some degree, the chemical characteristics of the manure can be altered by the ration that is fed the animals. If a low total salt ration is provided for the cattle, the manure will not contain as much sodium as that from animals fed a high salt ration or from animals allowed salt on a free choice basis. The amount of roughage used in the ration will markedly affect the amount of manure produced, as shown in Table V-2. The amounts of manure accumulation in this table were measured by cleaning the lot after a cycle of cattle and reflect any biological reduction which occurred on the pen surface.

Feeding an all-concentrate finishing ration to feedlot cattle resulted in 2.3 pounds of dry waste daily accumulation per head. A 12 percent roughage finishing ration resulted in 5.0 pounds, and a 10 percent roughage ration resulted in a 4.4 pounds of dry waste per animal per day (14).

Many solid wastes properties are not known or are highly variable for wastes coming from open feedlots which affects the physical and chemical characteristics of the waste. Rainfall runoff carries some of the solid wastes from the feedlot surfaces and the cattle may cause a mixing action by trampling the manure into the soil. In the latter case, some soil may be removed with the manure when the feedlots are cleaned. Also, biodegradation of the solid waste material will occur under favorable temperature and moisture conditions. Increasing the density of the cattle in the feedlots usually increases moisture content of the feedlot surface. When feedlot surfaces become dry, some waste constituents, including odor components, are associated with the dust carried by the wind from the feedlots. Odors are most prevalent when feedlot surfaces are moist and temperatures are high enough for bacterial action to occur.

TABLE V-2

SOLID WASTE ACCUMULATION DURING THE FEEDING PERIOD (14)

	Experiment 1	
Item	All-concentrate Ration	12% Roughage Ration
Number of animals	23.0	24.0
Feed dry matter, lb.	60,768	77,110
Waste accumulation		
Total pounds	19,110	44,930
Dry matter %	47.0	46.9
Dry matter, lb.	8,982	21,072
Feed: waste ration,		
Dry matter basis	6.8:1	3.7:1
Animal days	3,950	4,237
Square feet/animal	95	88
Live weight, lb.	745	775
Daily dry matter waste accumulation		
Lb. per head	2.3	5.0
Lb. per 100 lb. live weight	0.31	0.65
Lb. per head per square ft.	0.024	0.057

Amount of Waste Removed from Pen

Typical amounts of solid wastes removed from feedlots with approximately 6 percent and 3 percent slopes, respectively, and located near Lincoln, Nebraska (5) and Pratt, Kansas (8) are presented in Table V-3. The dry matter removed in pounds per day per animal and the moisture content are shown so that the total weight of the material removed, including the moisture, can be calculated by Equation (V-I) (3):

$$TW = \frac{D}{1-MC} \qquad \text{EQN (V-1)}$$

where: TW = total weight, pounds/day/animal
MC = decimal percent moisture content, wet basis
D = dry matter removed, pounds/day/animal

Some of the values reflect cleaning after each pen of cattle has been fed whereas others represent two cycles of feeding before cleaning, the latter permitting nearly a year's accumulation of waste material in the feedlot. A comparison of the solids removed from an unpaved feedlot in eastern Nebraska to the slope of the lot is shown in Figure V-1.

A rule of thumb of approximately 1 ton of solid waste material per animal in the feedlot has been commonly used as the amount of solid waste material that has to be removed from an open feedlot. Based upon the central Kansas feedlot data (Table V-3) for a 150 day feeding period, the amount of dry material removed per animal ranges from approximately 0.75 tons/animal to about 1.2 tons/animal. If one considers that the moisture content of the material is approximately 40 percent wet basis, then the range in total weight of the solids removed per animal is from 1.2 tons to 2.0 tons per animal. From these data, it is apparent that considerable variation can exist in the amount of material removed from a feedlot. Some variation was probably attributable to cattle remaining in the pens for more than one feeding period before the material was removed, thus permitting more mixing of the soil and feces. When lots are operated under very sloppy conditions, mixing of soil and manure by cattle activity is increased. Soil mixing is probably greater on steeper slopes of 6 to 10 percent than on lesser slopes, such as the 3 to 6 percent slopes (Figure V-1). It has been shown by McCalla, et al., (10) that 55

TABLE V-3

SOLID WASTE REMOVED FROM FEEDLOTS (3)

Feedlot Location	Days Accumulated	Date of Removal	Animal Density (ft^2/animal)	Dry Matter Removed (Pounds/day/animal)	Moisture Content (% w.b.)
Eastern Nebraska	112	Nov. 7	100	8.6	52
	112	Nov. 7	200	5.7	54
	203	June 27	100	14.3*	33
	203	June 27	200	20.1*	40
South Central Kansas	163	Feb. 25	250	15.8	39
	290	Aug. 21	261	13.7*	34
	287	Oct. 7	238	15.9*	24
	153	Nov. 14	208	10.4	39

*Values based upon pen capacity rather than total number fed during two feeding periods.

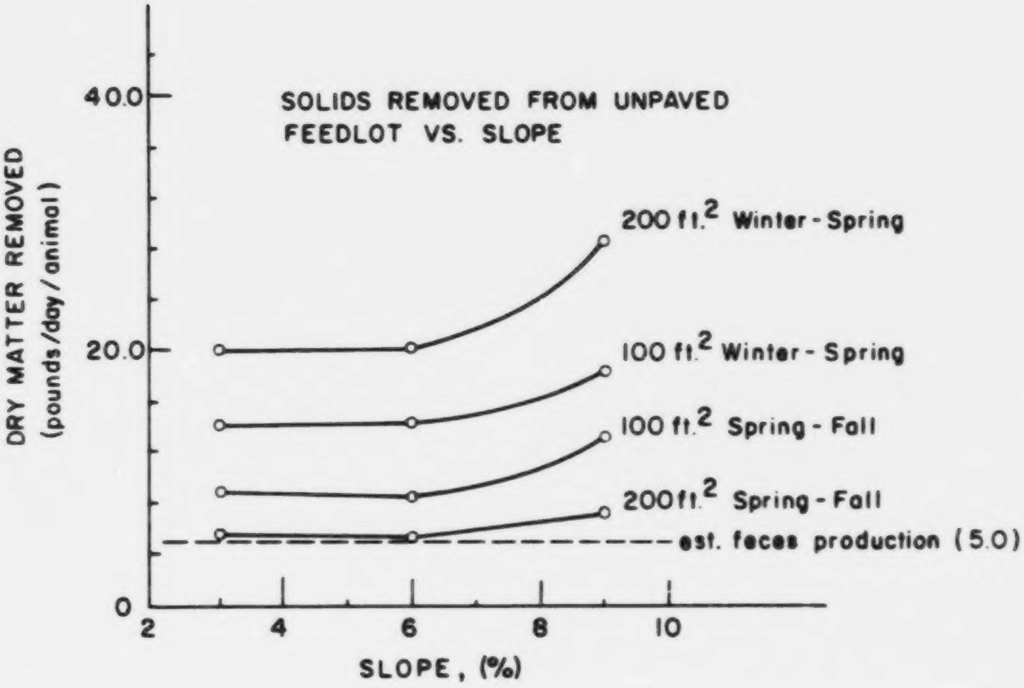

FIGURE V-1. THE EFFECT OF SLOPE ON THE REMOVAL OF SOLID WASTES FROM AN UNPAVED FEEDLOT IN EASTERN NEBRASKA (3).

percent of the fecal organic matter is biologically degraded on the lot itself. The Nebraska studies indicated that up to 95 percent of the dry material removed from the lot was soil.

Grub (6) found that if the accumulated waste is kept moist, either as a result of maintaining a high density of animals in the feedlot or as a result of weather conditions, biological degradation of the waste proceeds at a rate proportional to its temperature. As long as the moisture content of the waste exceeds about 40 percent w.b., a 10° C rise in temperature roughly doubles the rate at which degradation occurs. During dry weather, when the organic mass may contain as little as 2 percent w.b. moisture, very little biological or chemical activity occurs.

COLLECTION AND DISPOSAL

The methods of removing solid waste from a feedlot are many and varied. This section of the manual will deal only with solid floor design and wastes in the solid form. Slurries and water flushing to form slurries are discussed in Section VI.

The first step in removal of the manure from the lot surface is scraping the manure in piles or windrows. Care should be taken not to disturb the manure pack on the lot surface. This pack prevents the movement of moisture and pollutants downward into the water table; it also provides for an anaerobic zone at the interface between the pack and the soil which promotes denitrification and helps prevent nitrate movement beyond this zone (11). Once the manure has been scraped it may be removed from the feedlot with several machines or combinations thereof (Figure V-2). If the manure is to be stockpiled for sale or later application to cropland, large carryalls or trucks loaded with front-end loaders may be employed to transport the material to a suitable storage area. If the manure is to be transported immediately to a disposal site, spreader trucks will probably be used (Figure V-3).

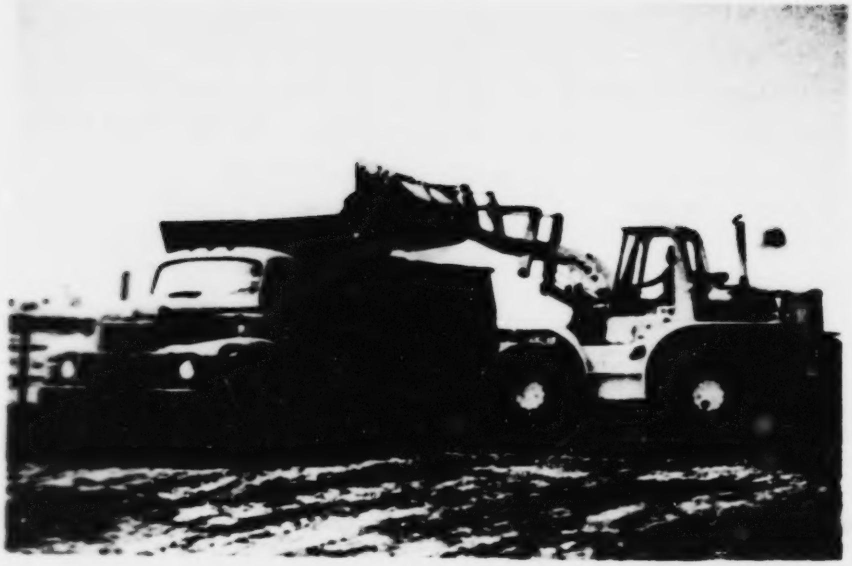

FIGURE V-2. LOADING MANURE IN SPREADER TRUCK USING A FRONT-END LOADER.

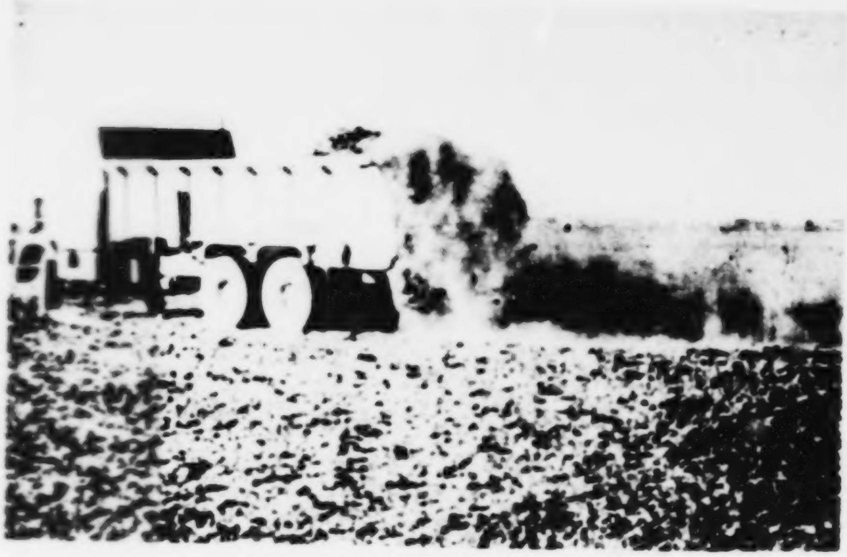

FIGURE V-3. SPREADING MANURE ON CROPLAND WITH SPREADER TRUCK.

In some feedlot operations the manure is simply mounded within the pen and left for the cattle to lie on in wet weather. This practice seems to be more useful in feedlots located on fine textured soils and the practice is used extensively in eastern Nebraska.

The factors affecting the removal of solid wastes from the feedlot and affecting the method of removal are:

1. moisture content of the wastes,
2. animal density (amount of wastes per acre),
3. length of time from previous cleaning,
4. amount and intensity of rainfall,
5. slope of lot surface,
6. size of pens,
7. total capacity of feedlot,
8. hauling requirements and ultimate disposal, and
9. soil type.

Storage of Solid Wastes

The storage of solid wastes from a feedlot presents several opportunities for possible water pollution problems.

Solid waste storage areas must be designed. They should not be located by simply deciding that a particular area is a handy place to pile manure. The storage area should be planned to eliminate all runoff water from other land areas thereby avoiding its contact with the stored manure. The drainage and runoff water originating in the storage area must be handled in the same manner as runoff from the feed pens. If possible, runoff from solid waste storage areas should drain by gravity into the runoff control system used by the feedlot.

TREATMENT AND DISPOSAL

Land Application of Solid Wastes

The disposal of animal wastes on agricultural land is one of the oldest fertilizer programs used by man. However, with the concentration of

TABLE V-4

CHARACTERISTICS OF SIX RECENTLY SAMPLED MANURES (1)

Dry weight percentage and pounds (per ton) on moist basis. Analysis percentages on oven-dry basis.

	Moisture Content		Dry weight		Organic Matter[1]		Sand[2]		Nitrogen[3]		Phosphorus[4] (P_2O_5)		Soluble[5] Salts		Soluble Cations[5]					
															Calcium & Magnesium		Sodium		Potassium	
Sample	%	lbs.	%	lbs.	%	lbs.	%	lbs.	%	lbs.	%	lbs.	%	lbs.	%	lbs.	%	lbs.	%	lbs.
Dairy	20	400	80	1,600	49	790	26	420	1.6	26	1.2	18	8.9	142	0.15	2.4	1.1	18.2	2.3	36.8
Feedlot A	52	1,040	48	960	62	590	22	210	1.8	17	1.3	13	10.6	102	.08	0.8	0.6	6.0	3.8	36.8
Feedlot B	31	620	69	1,380	53	725	29	400	1.9	26	0.8	12	8.0	110	.27	3.8	0.8	10.8	2.2	30.8
Feedlot C	25	500	75	1,500	40	600	38	570	1.6	24	1.4	20	9.5	143	.13	2.0	1.2	18.6	2.4	36.3
Feedlot D	20	400	80	1,600	44	700	41	660	1.6	26	1.2	19	4.2	67	.06	1.0	0.5	8.0	1.2	18.9
Feedlot E	24	480	76	1,520	38	575	47	710	1.4	22	1.0	15	7.2	109	.10	1.5	0.8	12.2	2.0	30.4
Average	29	568	71	1,430	48	668	34	496	1.65	23.5	1.14	16.3	8.1	112	0.13	1.9	0.85	12.3	2.3	31.7

[1] Oven-dry weight less weight of ash.

[2] Ash not soluble in hydrochloric acid.

[3] Total not including ammonia, etc., lost upon drying at 75°C.

[4] Total, by ashing 16 hours at 450°C.

[5] Determined in 1:20 manure:water extract.

large numbers of animals in feedlots and the availability and price of commercial fertilizers, many farmers are not interested in using animal wastes on their fields. For a quick review of the characteristics of a ton of feedlot manure see Table V-4. All the weights exclude water and are based on the dry weights of the components in a ton of manure. Application rates of manure will depend upon the characteristic of the wastes, the type of agriculture practiced on the land (pasture, dryland farming or irrigation), and on the soil type and existing salinity conditions of the soil. It can be seen from Table V-4 that soluble salts make up a considerable portion of the manure (about 8 percent on the average). Most research has indicated 10 to 30 tons of manure per acre annually will not affect crop production adversely; however, in some soils, salt accumulation may occur even at these rates.

Research being conducted by Kansas State University (EPA Grant 13040 DAT) at Pratt Feedlot, Inc., Pratt, Kansas, on irrigated land indicates that the maximum yield of corn forage was obtained with about 48 tons of dry manure per year (8). The results of this study are presented in Table V-5, wherein all amounts of manure are reported in dry tons.

TABLE V-5

MANURE APPLICATION RATES AND 1971 CORN FORAGE YIELDS (8)

Treatment	Manure Application, Tons/Acre[1] 1970	1971	Total	Corn Forage Yield[2] Tons/Acre
M 1	0	0	0	15.0
M 2	12	10	22	15.7
M 3	20	17	37	19.3
M 4	50	46	96	21.9
M 5	82	76	158	17.9
M 6	81	0	81	21.9
M 7	122	170	292	13.6
M 8	128	0	128	17.1
M 9	223	238	461	8.6
M10	236	0	236	18.3

[1] Average of four replications.

[2] Average of four replications; yield corrected to 70% moisture content.

Yield data from this study may present an over optimistic view, since the accumulation of salts in the soil profile may take more than two years to become critical at the lower application rates.

Table V-6 presents the electrical conductivity data from this same study and gives a better insight into the salinity problems associated with manure disposal.

TABLE V-6

ELECTRICAL CONDUCTIVITY OF SOIL SATURATION AS AFFECTED BY APPLICATION OF MANURE (8)

Treatments Tons/acre	Electrical Conductivity[1] Millimhos/cm
0	0.52
10	0.59
20	0.72
40	0.93
80	1.17
160	1.83
320	2.58

[1] Average of four replications

This data indicates slight salt increases up to 20 tons per acre. Only when the rate reaches 320 tons does the electrical conductivity approach a critical level for sensitive crops. Not all crops react to salt in the same manner; Red Clover, for example, is a sensitive crop, while Bermuda grass is very tolerant of high salt levels. If long term, heavy loadings of manure are to be applied to a tract of land, a salinity control program must be established to insure continued crop production. This program will require a detailed soil testing survey before any manure is applied and at regular intervals (usually annually) while the land is being used as a disposal site. A management system should be developed after the initial survey and should be followed carefully throughout the time the land is used as a disposal site. Assistance in developing such a program can usually be obtained from the Soil Conservation Service and the State Agricultural University.

Composting and Drying

Composting and drying have been investigated in some depth for animal wastes; however, only a few systems are in operation today. The success of composting and drying requires a market for the finished product. Since these markets are not yet available on a general basis, they must be developed (3). The high nitrogen and organic content of animal manures makes these wastes a desirable supplement to the composting of municipal wastes, and it is advantageous to combine the two whenever possible. Composting of manure does have two very important advantages: (a) the volume of manure is reduced by as much as 40 percent; (b) the temperature attained during the composting process will, in most cases, destroy the germination potential of any weed seeds in the manure (17).

Composting studies at Texas Tech University (7) have shown that the composting of feedlot manure is a feasible process. The success of the system is dependent upon several factors. The ratio of carbon to nitrogen in the manure should be at least 30:1. The moisture content of the manure on a wet weight basis must be at least 30 percent and should not exceed 50 percent. Since the compost pile may, and probably will, need more oxygen than it can obtain naturally, air will need to be forced through the pile. When all these conditions are met and the compost is stirred frequently, the process should have fly problems only in the very early stages of composting, and the odors should not be offensive. Composting time varies, dependent upon the condition of the waste, but should range from two to four weeks.

Because of its extremely high initial moisture content (approximately 85 percent wet basis), heated air drying of beef cattle waste requires only slightly more energy input than does evaporation from a free water surface, down to a moisture content of 25 to 30 percent wet basis. However, this requirement is high, between 1,000 and 1,100 BTU/pound of water at 100 percent efficiency. If the dried product itself is to be used as the fuel, it is necessary to reduce the moisture content to approximately 30 percent (wet basis) for combustion; its heating value has been found to range between 5,400 to 5,800 BTU/pound of dry matter. Using a conservative estimate of the energy requirement, a simple calculation demonstrates the economic infeasibility of drying schemes under most circumstances (9). Several animal waste drying systems have ceased operations because of odors and the lack of a profitable market for dried products (17).

Pyrolysis

Pyrolysis usually refers to the chemical decomposition of organic materials heated to a high temperature in an environment with insufficient oxygen to support combustion. This process might be termed "anaerobic incineration" to contrast it with normal incineration, which occurs in an excess of oxygen.

Pyrolysis is being used in wood distillation, coal coking, and petroleum refining and has also been investigated as a means of handling solid wastes such as wood, rubber, newspaper, corrugated box paper, lawngrass, citrus fruit wastes, and vegetable food wastes. The gaseous mixture from these materials yielded, among other things, CO_2, CO, H_2, CH_4, C_2H_4, C_2H_6, and N_2 (4). Some of these gases could be separated and converted to beneficial uses.

One of the advantages of pyrolysis is a reduction in the volume of total solids that require disposal. Another is that since the solid residue is dry and innocuous it can be stored and later used as a filler for fertilizer or disposed of by land filling.

From some of the research already completed and assuming that a market can be found for some of the products, it appears that pyrolysis of animal wastes is, at very best, a break-even economic system (4). If, however, the economic situation changes favorably for by-product recovery and use, pyrolysis might merit further consideration for application to animal wastes.

Refeeding of Animal Wastes

The idea of recycling or refeeding the manure produced by an animal back to that animal or to some other species of animal is not new. Many researchers and animal producers are presently experimenting with various methods of refeeding animal wastes. Anthony (2) has stated, "Organic waste collected from livestock reared in confinement can be effectively used as an animal feed."

Refeeding ideas vary greatly from adding raw manure directly to the feed to complete processing with harvest and subsequent feeding of produced protein. Refeeding of manure is not a common practice today; however, the concept is being researched and developed and may someday become feasible. A tremendous amount of research and testing must be done if such a process is to be accepted and legally added to the ration of any animal.

Taylor (13) points out in recent speeches that the FDA has not sanctioned and does not sanction the use of poultry litter as a feedstuff for animals and that Section 3.59 of the Code of Federal Regulations is a formal statement of policy regarding the use of poultry litter as a feedstuff for animals. Research in this area is not discouraged; however, the need for information on animal and human safety is stressed when animal wastes are proposed for use in the rations of livestock. At this time, the FDA does not have sufficient information to modify its present policy.

Though FDA policy relates to poultry wastes, it is safe to assume that all refeeding of animal wastes will fall under these constraints.

By-Product Recovery

The concept of by-product recovery has been the goal of almost all animal waste disposal and treatment systems discussed in this section. Researchers are working on conversion of animal wastes to fuel and oil products. One system for production of oil has been studied in the laboratory. Other researchers are working on conversion of manure to pipeline gas, and still others are considering conversion into synthesis gas for ammonia production. The conversion of municipal solid wastes into construction materials has been mildly successful both here in the United States and in foreign countries and this conversion idea is also being researched for animal wastes.

The above concepts are but a few of the many interesting and promising ideas that need more study and refinement before any of them are ready for widespread use by the animal production industry. These concepts stress the fact that the means of solid waste control will change with time and that no one idea or system is going to solve the solid wastes problems for all animal producers. Several systems are needed to allow the producer to select a system or combination of systems that will solve his special problem and be economically sound in relation to the total production unit for which it is designed.

CONCLUSIONS

The solid waste disposal problem for cattle feedlots is, for the most part, being solved today by spreading the manure on agricultural land. Some drying and composting systems are being successfully operated in locations where a market has been developed that will provide enough return to pay for the process.

Many reuse, recycle, and recovery systems are being studied today; however, none of these have been fully developed.

REFERENCES

1. Abbott, J. L., "Use Animal Manure Effectively," Bulletin A-55, Agricultural Experiment Station, University of Arizona, Tucson, Arizona (1968).

2. Anthony, W. B., "Cattle Manure: Reuse Through Wastage Feeding," Animal Waste Management, Cornell University Conference, Syracuse, New York (January 13-15, 1969).

3. Butchbaker, A. F., J.E. Garton, G. W. A. Mahoney, and M. D. Paine, "Evaluation of Beef Cattle Feedlot Waste Management Alternatives," Final Report, Grant 13040FXG, EPA (1971).

4. Garner, W., C. E. Bricker, T. L. Ferguson, C. J. W. Wiegand, and A. D. McElroy, "Pyrolysis as a Method of Disposal of Cattle Feedlot Wastes," Waste Management Research, Cornell University (1972).

5. Gilbertson, C. B., T. M. McCalla, J. R. Ellis, O. E. Cross and W. R. Woods, "The Effect of Animal Density and Surface Slope on Characteristics of Runoff, Solid Wastes and Nitrate Movement on Unpaved Beef Feedlots," Bulletin SB 508, Agricultural Experiment Station, University of Nebraska, Lincoln (1970).

6. Grub, E. W., R. C. Albin, D. M. Wells and R. Z. Wheaton, "Engineering Analysis of Cattle Feedlots to Reduce Water Pollution," Transaction of the A.S.A.E. No. 12, pp. 490-492, 495 (1969).

7. Grub, E. W., J. D. Martin, and L. L. Keeton, "Aerobic Stabilization of Beef Feedlot Wastes," Paper No. 70-909, presented winter meeting A.S.A.E. Chicago, December 8-11, 1970.

8. Kansas State University, "Demonstration and Development of Facilities for Treatment and Ultimate Disposal of Cattle Feedlot Wastes," Unpublished Interim Report, Project Number 13040 DAT, EPA.

9. Loehr, R. C., "Pollution Implications of Animal Wastes--A Forward Oriented Review," Robert S. Kerr Water Research Center, FWPCA, USDI, Ada, Oklahoma (1968).

10. McCalla, T. M., L. R. Frederick, and G. L. Palmer, "Manure Decomposition and Fate of Breakdown in Soil," published as Paper No. 2742, Journal Series, Nebraska Agricultural Experiment Station, University of Nebraska, Lincoln (1970).

11. Mielke, L. N., J. R. Ellis, N. P. Swanson, J. C. Lorimore, and T. M. McCalla, "Groundwater Quality and Fluctuation in a Shallow Unconfined Aquifer Under a Level Feedlot," Paper presented at the Cornell Agricultural Waste Management Conference, Rochester, New York, January 19, 1970.

12. Richards, L. A., Diagnosis and Improvement of Saline and Alkali Soil, Agricultural Handbook No. 60, USDA (February 1954).

13. Taylor, J. C., "Regulatory Aspects of Recycled Livestock and Poultry Wastes," Proceedings of International Symposium on Livestock Wastes, Ohio State University (1971).

14. Texas Tech University, "Characteristics of Waste from Southwestern Cattle Feedlots," Water Pollution Control Research Series, Grant 13040DEM, EPA (1971).

15. Train, R. E., R. Cahn, and G. J. McDonald, "Environmental Quality," The First Annual Report of the Council on Environmental Quality, Washington, D. C. (1970).

16. Viets, F. G., Jr., "The Mounting Problem of Cattle Feedlot Pollution," Agricultural Science Review, Vol. 9, No. 1, First Quarter (1971).

17. Wiley, J. S., "A Report on Three Manure Composting Plants," Compost Science 5:15 (1964).

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LIQUID SLURRY WASTES TECHNOLOGY

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SECTION VI

LIQUID AND SLURRY WASTES TECHNOLOGY

Liquid/slurry beef wastes management systems can be defined as those which handle material having a moisture content equal to or greater than 85 percent, wet basis, the average moisture content of fresh excreta. Such systems typically perform four functions: (a) waste collection and transport to storage, (b) storage/treatment, (c) transport from storage, and (d) reuse, further processing, or disposal. In addition, solids separation processes may be employed.

Slurry systems have the following characteristics:

1. A high degree of mechanization is possible, with consequent reduction of labor as well as unpleasantness in waste handling tasks.
2. Nutrient retention and availability to crops can be maximized.
3. A high degree of insect, odor, and water pollution control is possible.
4. Only one set of waste handling and storage components is needed, rather than both liquid and solids equipment.
5. Frequency of disposal is controlled by the size of the temporary storage/treatment holding structure(s).

A variety of unit processes is available to accomplish these functions.

The remainder of the section is organized according to the five above-mentioned functions: collection, storage/treatment, transport from storage, solids separation, and reuse/disposal. A unit operations approach is used, describing each component separately but noting the pertinent characteristics necessary to incorporate it in a system design; common combinations of systems components are mentioned. Occasional cross-reference to related topics in Section IV, Runoff Carried Wastes, and Section V, Solid Waste Control, is made.

WASTE COLLECTION AND TRANSPORT TO STORAGE

Beef feedlot facilities utilizing liquid/slurry wastes handling systems fall into two groups: (a) slotted floor confinement buildings, and (b) solid floor buildings or paved open lots. Selected combinations for collection and transport of wastes from these housing systems are shown schematically in Figure VI-1. Hybrid systems utilizing slats in combination with solid floors, are also common; these require periodic scraping of the solid portion or flushing with fresh or recycled water. Further discussion of slotted floors is found in Section II in the section entitled "Total Confinement Buildings;" the possibility of intermediate solids removal is discussed later in Section IV under section title: "Solids Separation Processes."

Tractor-mounted Scrapers

The use of tractor-mounted scrapers is applicable to paved open lots and to confinement buildings having a solid or partially slotted floor. Several scraper designs are reported in use by Payne (40):

1. pull type scrapers having fixed wings on the end of the blade to retain the slurry,
2. pull type scapers with hinged wings on the blade ends (for improved efficiency on sloped surfaces),
3. push type blades with either wing option, and
4. multi-purpose scoops or buckets.

For small enterprises or tight corners, 2-wheeled, powered, walking scrapers are also available.

Shallow Underfloor Pit Scrapers

Three types of scrapers are used in shallow pits beneath slotted floors (40):

1. winch-powered scrapers having blades up to approximately 10 feet in width and with a maximum travel of 525 feet;

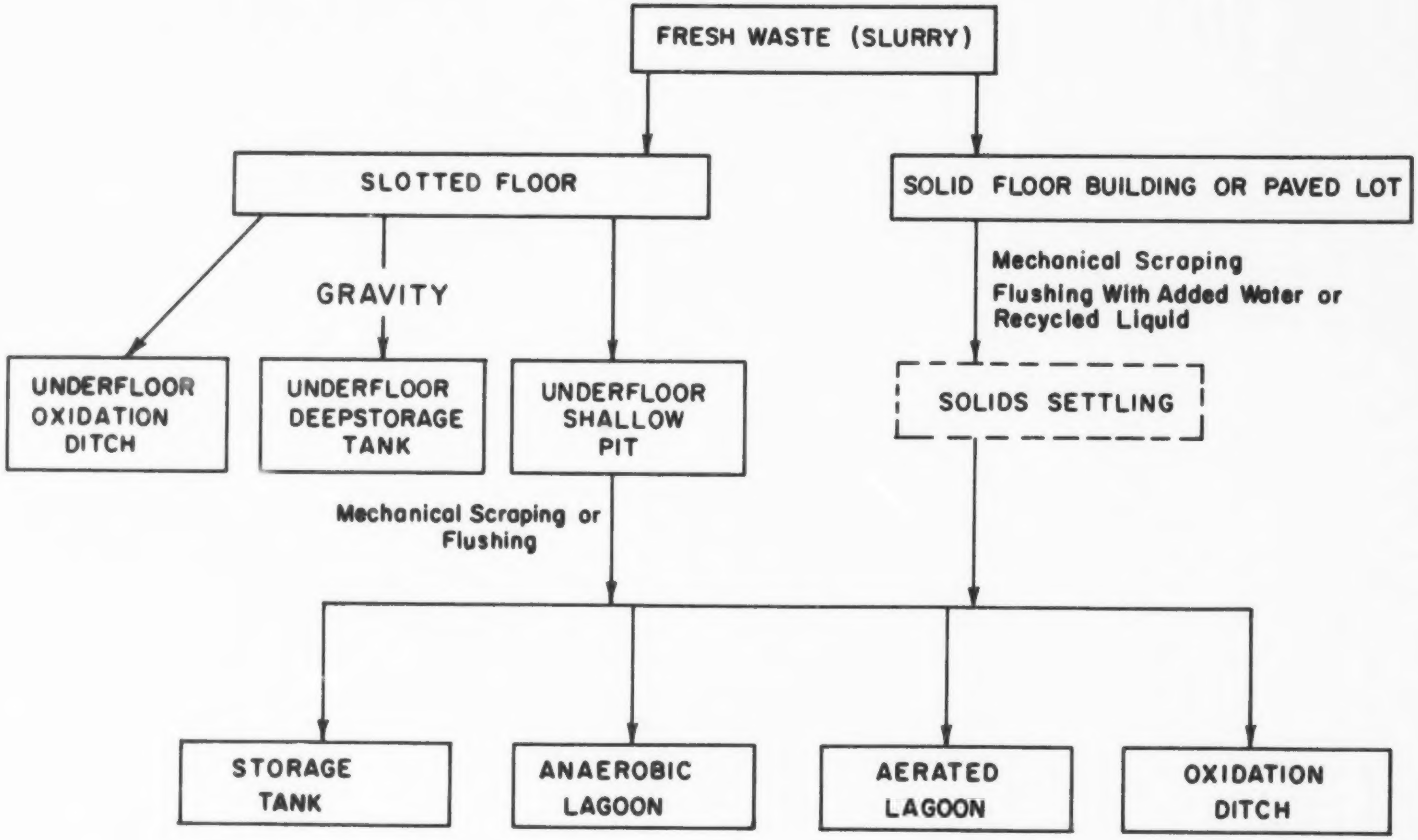
FRESH WASTE (SLURRY)
SLOTTED FLOOR
SOLID FLOOR BUILDING OR PAVED LOT
GRAVITY
Mechanical Scraping
Flushing With Added Water or Recycled Liquid
UNDERFLOOR OXIDATION DITCH
UNDERFLOOR DEEPSTORAGE TANK
UNDERFLOOR SHALLOW PIT
SOLIDS SETTLING
Mechanical Scraping or Flushing
STORAGE TANK
ANAEROBIC LAGOON
AERATED LAGOON
OXIDATION DITCH

FIGURE VI-1. SELECTED OPTIONS FOR COLLECTION AND TRANSPORT OF LIQUID/SLURRY WASTES TO STORAGE.

2. reciprocating scrapers having blades which open on the forward stroke and fold on the return stroke, intermittently moving the waste into a collection structure (these are reported to have a maximum width of approximately 6 feet and a maximum length of 200 feet); and
3. continuous chain and flight (gutter cleaner) scrapers up to 1.5 feet in width and making a maximum 450 foot circuit (due to their narrow width, these may be used primarily as a transfer conveyor to the storage structure).

Pits are normally only 1 to 2 feet deep, and are scraped at least daily to minimize fly and odor problems in the building. Slurry storage can be in a pit located at one end of the building, in an outdoor lagoon, or in an underground tank.

Hydraulic Transport

An alternative to scraping solid floor confinement buildings and paved open lots is flushing the waste from the surface to a storage structure. With proper design, such a system can be made essentially automatic. However, even with recycle of wastewater for flushing, an appreciable volume of fresh water must be added to facilitate pumping and to transport the solids load. This increases the amount of liquid which must be stored, treated, and disposed of. Additional disadvantages for paved lots in cool climates are continuous dampness and possible frozen surfaces.

Prediction of solids transport in a flushed system is difficult. The following expression has been suggested to describe the parameters of the process (41):

$$T = N\,(SQ)^{5/3} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad \text{EQN (VI-1)}$$

where:
T = sediment carrying capacity, lb./ft.^{3}
N = a constant dependent on particle size and density
S = surface slope, decimal
Q = discharge flow rate, ft.^{3}/min.

By a simple test measuring slope, discharge rate, and weight of solids transported, the constant can be determined for the waste being flushed; knowing the waste production rate and surface slope, Equation (VI-1) might then be used to predict the flow rate needed in the system. In systems flushed with a hose, a flow rate of 4,500 gallons per hour at 15 psig through a 1-inch nozzle was found to be sufficient (40).

A 12,000 head Texas feedlot is reported to use a hydraulic flushing system on pens having a 2 percent slope (4). In this operation, flushed wastes are collected in a 12-inch underground sewer line located at the lower end of each 100 ft. x 260 ft. pen. The 12-inch lines then join a 36-inch main leading to a 500,000 ft.^{3} concrete reservoir, from whence the slurry is pumped for irrigation. No flow rates for the system were given.

In a Canadian confinement housing facility, dairy cattle wastes underneath a slotted floor are flushed periodically by the rush of water from a suddenly-opened sluice gate into a pumping pit (52). This cycle is repeated using a 2 to 3 foot head of dilute slurry until all solids have been washed into the pit. At 9 to 10 percent solids, the slurry may be removed by tank wagon or pumped to a holding tank for long-term storage.

In another installation, a small experimental confinement building with a shallow pit beneath a slotted floor employed only treated and recycled wastewater as the flushing medium (43). Solids settling followed by various anaerobic, aerobic, and chemical treatments all failed to produce an effluent with odor levels acceptably low for flushing; the recycled wastewater also developed an aesthetically displeasing dark color. From these results, it would appear that dilution water is necessary for recycle of flushing water. In tests with swine wastewater (18), however, the Barriered Landscape Water Renovation System (Liquid and Slurry Waste Storage/Treatment, Section VI) produced an effluent suitable for flushing; such a treatment, coupled with solids settling, shows promise as a beef wastes handling system.

LIQUID AND SLURRY WASTE STORAGE/TREATMENT

Because animal excreta are in a state of virogous decomposition from the time they are produced, no feasible detention structure will serve strictly as a storage without also permitting additional breakdown of the wastes. Choice of one or more storage/treatment options is a function of: (a) the method of waste collection and the resulting waste volume, (b) the maximum period of storage required, (c) the type and degree of processing to be given the waste, (d) pollution control requirements while in storage, and (e) the means of ultimate use or disposal of the waste.

Liquid and slurry waste treatments fall into two major classes, aerobic and anaerobic, based on the degree to which oxygen is available to decomposition microorganisms. No chemical or physical liquid/slurry treatment processes (other than solids separation) are presently in common use in beef feeding enterprises; hence the two classes, aerobic and anaerobic, plus combined aerobic-anaerobic treatment, will be used as the basis for discussion of the intermediate stages of a liquid/slurry waste management system. At the present time, no proven storage/treatment exists which will produce an effluent suitable for discharge to a watercourse; therefore, treatments presented in this section cannot be viewed as a means to ultimate disposal.

In the subsections which follow, major factors of choice for each component are first enumerated to enable the user to determine his potential interest. Next, special considerations of site selection and climate are discussed.

Finally, component design, construction, and management are detailed for use in intensive planning.

Anaerobic Storage/Treatment Components

Anaerobic waste decomposition processes take place in an environment lacking free oxygen gas. The chemical kinetics of these processes are extremely complex and are not completely understood. A central fact to remember in design and management of an anaerobic process is that contact with atmospheric oxygen must be minimized.

Important characteristics of the anaerobic decomposition process are given by Miner (35):

1. A large percentage of the gas given off is methane (natural gas), which can potentially be used as an energy source for heating, generation of electricity, etc. In some cases, the explosive nature of this gas can create a hazard.
2. A major reduction in slurry solids content is achieved through anaerobic decomposition processes, reduction of sludge buildup in the storage and promotion of good liquid material handling characteristics.
3. Well-decomposed sludge from the process has only a slight musty odor and is readily dewatered by free drainage. These characteristics favor land disposal, with minimum nuisance problems.
4. Minor gases given off from partially anaerobically decomposed matter are both noxious and toxic, producing potential nuisance and safety hazards in storage and during slurry land disposal operations.
5. Like all biological processes, anaerobic decomposition is quite temperature dependent, with maximum efficiency reach well above common ambient temperatures. A pH of 6.5 is considered optimal.

6. Pesticides, antibiotics, salts, and other residues are toxic to bacteria and will, in significant amounts, impair treatment efficiency.
7. Since effluents of anaerobic treatment processes are too pollutionally potent for discharge to a watercourse, land disposal is commonly practiced. Three anaerobic components have been used to store/treat animal wastes: (a) storage tanks, (b) anaerobic lagoons, and (c) anaerobic digesters.

Anaerobic Tank Storage

A common type of slurry storage associated with slotted floor confinement buildings and small paved lots is the underground tank. This structure, which may be located under the floor of the housing facility or beneath an outdoor slab, is used primarily to provide flexibility in the scheduling of land disposal operations, rather than for treatment. A typical tank is constructed of reinforced concrete with a depth of 8 to 10 feet and is sized according to the number of animals it serves and the number of days between spreading operations.

Considerations in the choice of this component are:

1. Due to the high capital cost per unit volume, it is necessary to restrict the amount of water entering with the excreta. This may preclude the use of a flushing system and will require precautions to prevent the entrance of rainwater and runoff.
2. The storage capacity needed will depend on the animal population and the disposal schedule. One cubic foot per 950 pound animal per day is a common design figure; in the northern Midwest, 6 months of storage may be necessary.
3. Land disposal is the only common use of anaerobically stored wastes; specialized slurry agitation and materials handling equipment are needed. Maximum percentages of fertilizer nutrients are retained by this storage method.

4. A well-constructed tank will permit no groundwater pollution via seepage. During storage, the quiescent slurry and covered tank tend to minimize odor problems. Tank agitation and spreading operations, however, release strong noxious odors.

Site Selection. To minimize possible contamination of groundwater, the tank should be located downgrade and at least 100 feet away from the water supply well (33, 46). Unstable soil or fractured bedrock under the tank can cause uneven settling and consequent cracking of the structure; such locations should be stabilized or avoided. Flotation and failure due to external hydrostatic pressure may occur if the tank is located below a high water table or on a flood plain. A location downwind from nearby neighbors will minimize the chance of odor complaints.

In new confinement housing facilities, building the tank beneath the slotted floor achieves some inherent cost saving, since the floor and footings of the building are incorporated into the structure of the tank; however, constant forced-draft ventilation of these tanks to the outside is necessary. Tanks not open to the building do not require constant ventilation.

Sizing the Storage. The volume required for slurry storage depends not only on the number of animals in the production unit and their ration and environment but also on the management of the system and the handling techniques employed. The information necessary to estimate the required volume is detailed here; construction plans can be obtained from consultants, equipment manufacturers, contractors, and the Cooperative Extension Service at land grant universities.

In choosing a tank design, cost of construction should be balanced against usable storage volume and materials handling characteristics. Tanks having circular or square cross-sections tend to enclose a given volume with the least surface area; the lids, however, may require extra strength or internal supports and thus increase cost and/or decrease effective volume. Circular shapes also promote good agitation, which is required before the tank is emptied. Some square and rectangular tank designs employ internal concrete baffles to achieve better mixing of the contents; alternatively, the tank can be divided by walls into several interconnected cells, each of which is agitated separately with a low powered agitator.

Besides the potential storage space taken up by internal structures, an appreciable volume may be lost due to dilution water, spilled feed and drinking water, tank head space, and the inability of the pump to completely empty the tank. The following expression summarizes the factors which determine the adequacy of a proposed tank storage design:

$$S = \frac{V - I - H - P - E}{N(X+D)} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{EQN (VI-2)}$$

where: S = estimated storage time, days
V = gross internal volume of storage tank, $ft.^3$
I = sum of volumes of internal baffles, column supports, mounted agitator, etc. $ft.^3$
H = head space volume, $ft.^3$
P = volume below pump intake, $ft.^3$
E = volume lost to extraneous feed, drinking water, etc., $ft.^3$
N = number of animals
X = excreta production, $ft.^3$/animal/day
D = dilution volume added, $ft.^3$/animal/day

Parameter values necessary for this calculation can be estimated from a construction plan and from the following discussion.

To fit the disposal schedule to other feedlot operations and climatic constraints, the storage period should be determined. In the north, a storage capacity of 6 months may be required to avoid disposal on frozen or snow covered soil and wet field conditions. Storage of 3 months or less may be adequate in other areas; the tendency is, however, to underestimate the volume required. In totally slotted confinement buildings in Illinois, stocked with 700-1,000 lb. cattle at a density of 18-20 ft.^{2}/head, storage pits were observed to fill at an average rate of 1 foot depth per month (25).

Daily production of excreta varies with breed, ration, and environment. In the absence of better information, a 950 pound beef animal produces approximately 1.0 ft.^{3} per day of feces and urine at 85 percent moisture content wet basis (31); this value may be used as an average over the growing period. Dilution of the slurry to 94 to 96 percent, wet basis, has been suggested (27) as a compromise between excessive storage volume and excessive power requirements for pump and agitator. This would require the addition of at least 2.3 ft.^{3} (17 gal.) of water per animal per day. Extraneous materials, such as spilled feed, should be excluded from the tank as much as possible; drinking and storm water should be diverted from the storage.

Two other sources of lost storage volume may be significant. To avoid clogging the manure pump with unmixed or fibrous solids, the intake is normally located 8 to 12 inches off the bottom of the tank; hence, after the tank is initially filled, this volume cannot be reused. It is also recommended that the tank be emptied when 8 to 12 inches of head space remain. In tanks located beneath confinement buildings, this permits ventilation of gases from the pit to the outside atmosphere; the space is also needed for agitation.

Tank Construction. A preferred material for storage tank construction is poured reinforced concrete; farm building contractors and silo manufacturers often have prefabricated forms for this purpose (33).

Commercial steel storage tanks especially designed to resist corrosion by manure are also being installed. Precast concrete wall sections are not designed for top loading; if these are used, the tank must be given additional support. Concrete block, tile, and wooden tank construction should be avoided, since these structures will eventually leak. Insulation of an outdoor tank is necessary in northern climates.

Slurry storage tanks located outside the housing facility should have openings slightly elevated above the surrounding surface to prevent entrance of runoff. An opening approximately 8 inches wide and the length of the blade, and having a tight-fitting lift-off cover of steel or treated lumber, works well for tractor-scraped lots. Additional tight-fitting lids should be provided for the pump and agitator access openings. Within the tank, a permanent emergency ladder or steps should be placed beneath each opening having a width of 15 inches or greater.

Agitators. Within a storage tank, unagitated beef cattle wastes form a thick crust of solids above the liquid fraction; this must be broken up by agitation before pumping. If agitation is done regularly, three layers form: the crust of light solids, the intermediate liquid, and a bottom layer of sand, grain, etc. This bottom layer can be extremely hard to pump. Particular care must be taken in the placement of agitator and pump access openings. Equipment manufacturers' recommendations should be followed; effective agitator radius is normally 20 to 30 feet. A comparison of agitators is given in Table VI-1.

Tank Storage Management. Before use, tanks located beneath slotted floors should be loaded with 3 to 4 inches of water; those to be filled with scraped wastes should initially have a depth of 6 to 12 inches of water (33). This practice will prevent drying of solids on the tank bottom and retard the development of odors.

Although constant addition of dilution water to the tank is not necessary, considerable agitation may be required to reentrain the solids if moisture is not added periodically; dried scrapings added to the tank are likewise difficult to break up. Frozen manure should not be added to the tank since this may initiate freezing of the storage, possibly causing structural damage.

TABLE VI-1

SLURRY AGITATION EQUIPMENT (40)

Item	Description	Effective Agitation Volume, Gal	Remarks
Vaccum-type tank wagon	Agitation by means of air blow-back from tank prior to field spreading	Up to 12,500	Combines agitator, pump, and tank wagon in a single unit. High labor demand. Low equipment cost.
Centrifugal chopper-type manure pump	Recirculation of slurry in tank prior to pumping, typically 2000 gpm, tractor driven.	Up to 37,500	Combines agitator and pump in one unit. Low equipment cost, high labor demand.
Propeller mixer, portable (up to 13 ft. shaft)	10 HP electric powered	Up to 40,000	Relatively low equipment cost, high tractor and labor demand. Can break up surface crust.
	tractor-driven	50,000-75,000	
Auger	Large diameter unshielded screw.	Approx. 25,000	Relatively low equipment cost, high operating cost.
Fixed reel or paddle type agitators with 3-5 Hp electric motor drive, daily operation.	Horizontal type	50,000	High equipment cost but low labor demand after operated by time clock.
	Vertical type	12,500	

All tank access openings should normally be kept closed; this practice not only prevents accidental entry of animals, humans, and objects but also aids in controlling insect and odor nuisances. A regular program of insect control plus careful periodic cleanup around storage openings can eliminate fly problems.

One of the primary hazards of slurry storage is the generation of noxious gases during the anaerobic decomposition process; these may cause asphyxiation of animals or humans. Table VI-2 identifies some properties of the major decomposition gases. Ventilation fans should be used to draw warm air from the building through the pit and exhaust noxious gases to the outside. This arrangement also inhibits freezing of outdoor underground tanks in cold weather. Minimum airflow through the pit space should be 15 cfm per 1,000 lb. of animal weight (3).

TABLE VI-2

PROPERTIES OF ANAEROBIC DECOMPOSITION GASES (50)

Gas	Weight Air = 1	Physiologic Effect	Other Properties
CH_4 Methane	1/2	anesthetic	odorless, explosive
NH_3 Ammonia	2/3	irritant	strong odor, corrosive
H_2S Hydrogen Sulfide	1+	poison	rotten-egg odor, corrosive
CO_2 Carbon Dioxide	1 1/3	asphyxiant	odorless, mildly corrosive

Due to the thickness of the slurry in well-managed storage tanks, the waste is normally hauled in tank wagons to the field for spreading, rather than irrigated. The proper consistency of a well-agitated slurry is that of a thick cake batter. Insufficient dilution will cause difficulty in pumping; excess water will permit separation of solids before the tank can be emptied.

During agitation prior to emptying, trapped pockets of gases will be released. To prevent a buildup of these to toxic or explosive levels, the tank should be ventilated prior to and during agitation; animals housed in slotted floor buildings should be evacuated. If it becomes necessary to enter the tank at any time, the National Safety Council makes the following recommendations:

1. Never work alone.
2. Use a lifeline and make sure sufficient power is available to lift the person from the tank.
3. Ventilate the tank before entering and during the time the tank is occupied.
4. Check for combustible gases and oxygen level with an appropriate testing device.
5. If in doubt, use a self-contained breathing apparatus.

Anaerobic Lagoon Storage

A second anaerobic storage/treatment is the lagoon, a deep earth-diked pond, typically having several months' storage capacity. Although the surface is in contact with atmospheric oxygen, the depth, high solids loading, and lack of agitation keep the decomposition process anaerobic. Lagoons can be loaded by flushing or scraping. Because of decomposition, settling of solids, and added precipitation, the fluid is less viscous than the slurries found in storage tanks and can be irrigated with a properly designed system.

Additional factors regarding lagoons are (35):

1. Lagoons are easily constructed with conventional earthmoving equipment at a low cost per unit volume.
2. A lagoon provides flexibility in scheduling of land disposal operations; in warm climates, there is also a considerable reduction in sludge solids.
3. Because of the noxious odors associated with anaerobic decomposition, during warm weather the lagoon can be a serious nuisance. Proper design and management can often minimize this hazard, however.
4. Effluent from anaerobic lagoons is not suitable for discharge to a watercourse.

Site Selection. In addition to locating the lagoon at a site convenient for loading and discharge, several additional factors must be considered. Because anaerobic lagoons can be the source of odor problems, a location downwind from nearby neighbors, if possible, is a prudent choice. To fill the lagoon initially and for later regulation of its level, an available, easily controlled source of water is required; similarly, during wet seasons, overflow may have to be diverted to accessible fields for irrigation. In choosing a site, it is tempting to make use of natural depressions in order to reduce the volume of earth to be moved. However, it is first necessary to insure that the lagoon will be above the groundwater table, above flood levels, subject to minimum erosion, and located such that surface runoff from the surrounding area can be readily diverted (35).

An evaluation of soil permeability and geologic structure by the Soil Conservation Service will indicate if sealing of the lagoon bottom is necessary to prevent exfiltration. A plastic liner, polyphosphates, or Bentonite clay may be used for this purpose; the clay must be kept continously wet to prevent cracking and subsequent leakage.

Sizing the Lagoon. Three main factors--animal population, climate, and length of storage period--influence the minimum allowable storage volume for an anaerobic lagoon. Storage is required for dilution water, sludge accumulation, and precipitation. To estimate total volume, the following procedure is suggested:

1. Estimate permissible loading rate based on local climate, as follows (35):

Climate	Loading, lb. Volatile Solids/Ft.^{3}/Day
Moderate mid-western	0.005
Severe winters	0.0033
Warm winters	0.0067

Areas of similar climate are shown in Figures II-1 and II-3. Excreta of a 900 lb. steer contains 7 lb. volatile solids/day (29); this may be taken as average over the growing period.

2. Calculate liquid volume needed:

$$V_L = \frac{7. \times N}{L} \quad \text{.................................} \quad \text{EQN (VI-3)}$$

where: V_L = required liquid volume, ft.^{3}
N = number of cattle
L = loading, lb. volatile solids/ft.^{3}/day

3. Calculate storage volume of accumulated sludge. As a rough rule of thumb (20), 20 lb. volatile solids equal 1 ft.^{3} of sludge. Hence,

$$V_S = \frac{7. \times N \times D}{20} \quad \text{..............................} \quad \text{EQN (VI-4)}$$

where: V_S = sludge storage volume needed, ft.^{3}
N = number of cattle
D = length of storage period needed

4. Calculate minimum waste storage volume required:

$$V = V_L + V_S \quad \text{.......... EQN (VI-5)}$$

Additional storage for precipitation is allowed by incorporating at least a 2-foot freeboard in the design (13).

Successful functioning of the lagoon is also largely dependent on its shape. By making the excavation as deep as feasible with maximum permissible side slopes and minimum surface area (square or circular), several benefits are derived:

1. Heat lost by convection to the atmosphere is minimized; surrounding soil acts as insulation.
2. Internal mixing of the lagoon is enhanced.
3. Diffusion of odors into the air is minimized.
4. Excavation cost is usually minimized.

A further consideration in choosing the lagoon shape is the mode of cleanout of the solids accumulation. For example, if a dragline is to be used, it is necessary to limit the lagoon width to about 50 feet. In this case, it may be desirable to use a rectangular cross-section; nevertheless, for good mixing the length to width ratio should not exceed 3:1 (13).

Lagoons utilizing natural topography may include shallow bays somewhat isolated from the main body of water in which the solids cannot be well-mixed; therefore, they often are the source of odor problems. In constructing the lagoon, these shallow bays should be eliminated.

Side slopes should be chosen such that severe erosion will not occur before grass cover is established and should not be too steep to allow safe mowing (3:1 is typical). Lagoon depths of 14 feet or greater are common.

In areas of large moisture deficit (see Figures II-1 to II-13), sufficient evaporation may occur to eliminate the necessity for disposal of the liquid waste fraction. In this case, the required surface area is calculated from:

$$A = \frac{0.0134Q}{D} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{EQN (VI-6)}$$

where: A = surface area of lagoon, acres

Q = daily waste flow, gallons

D = moisture deficit, inches

However, to satisfactorily evaporate the entire moisture load, a shallow pond design is more efficient; see Section IV, "Evaporation Disposal." Finally, based on the previous considerations, the excavation volume of square or rectangular basins can be calculated from:

$$V = blh + Sh^2(b + l) + 4/3\ S^2h^3 \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{EQN (VI-7)}$$

with symbols defined as shown in Figure VI-2.

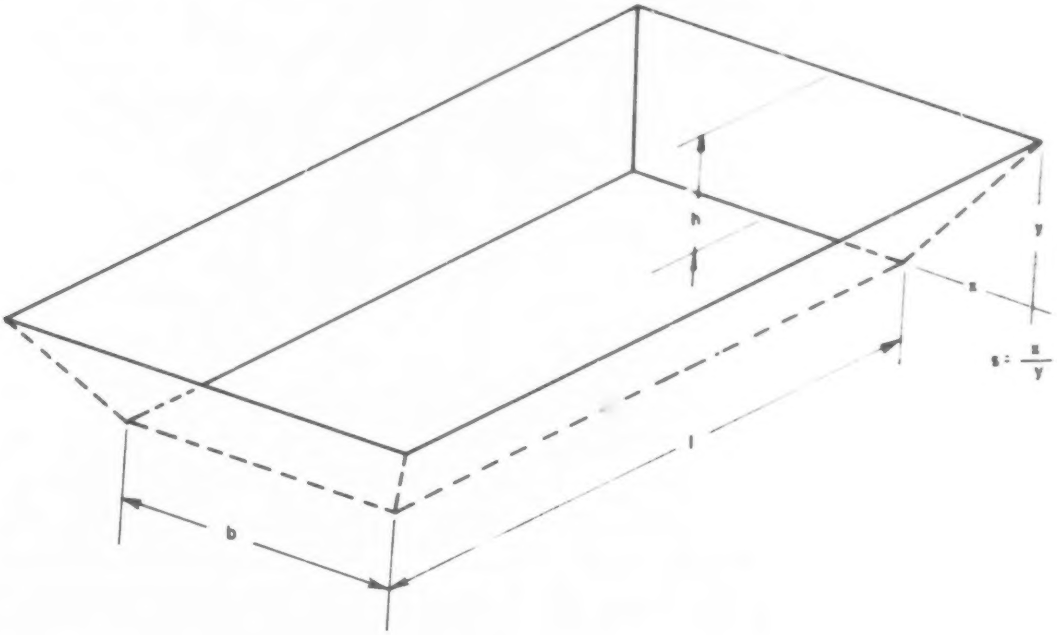

FIGURE VI-2. SCHEMATIC VIEW OF LAGOON WITH DIMENSIONS (13).

Lagoon Construction. Lagoon excavation is done with conventional earthmoving equipment according to the design chosen; sealing the surface of the soil, as discussed in the Site Selection subsection (page III-19) should be done at this time.

Discharge may be transported to the lagoon by gravity flow or pumping. For gravity flow systems, transport using a trough, rather than a pipe, will require less dilution and facilitate cleanout. The preferred location for the lagoon inlet is near the center of the impoundment. Where sufficient flow is available to prevent clogging of the line, a submerged inlet will aid mixing and inhibit freezing.

Because a scum often covers the lagoon surface and solids build up on the bottom, the outlet should be designed to empty the lagoon from an intermediate depth or, by means of baffles, to exclude scum from the discharge. Alternatively, a deponding hose may be used, as shown in Figure VI-3.

The area around a lagoon should be diked to prevent surface runoff from entering the impoundment; this extraneous water reduces storage capacity.

In like manner, all water not falling directly on the animal confinement area should be diverted from the lagoon. For example, roof drains from confinement buildings can be directed away from waste-bearing channels. Lagoons should be fenced for the protection of children and livestock and the fence located so that it will not interfere with maintenance of the dikes or mowing area. Gates should be provided for machinery access (13).

Management of Anaerobic Lagoons. The primary management aspect of anaerobic lagoons is the control of odor; this problem can be attacked from several directions. Proper scheduling of liquid and sludge removal operations can be effective. Like all biological systems, the performance of the anaerobic lagoon is highly temperature dependent. Thus, under severe winter conditions little degradation takes place and odor is negligible. At the onset of warm weather, manure previously deposited in

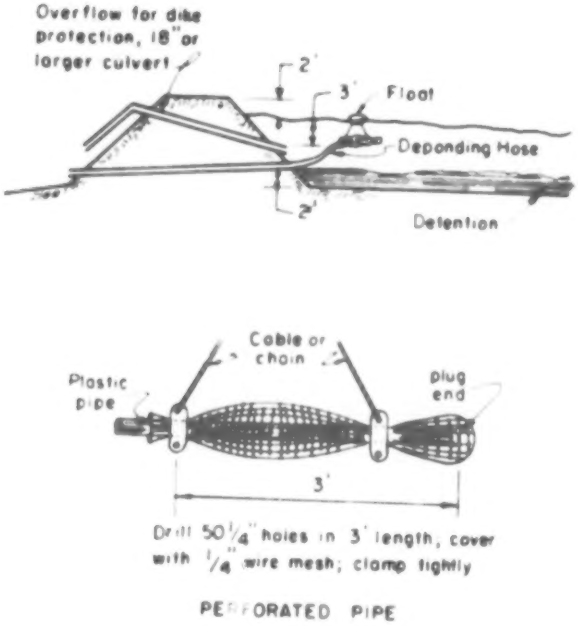
Overflow for dike protection, 18" or larger culvert
2'
3'
Float
Deponding Hose
2'
Detention
Cable or chain
Plastic pipe
plug end
3'
Drill 50 1/4" holes in 3' length, cover with 1/4" wire mesh; clamp tightly
PERFORATED PIPE

FIGURE VI-3. DEPONDING HOSE (3).

the impoundment becomes available to the decomposition bacteria; it is at this time that adverse odor conditions are most common. If the lagoon is to be used primarily as a winter storage, early spring land disposal (as soon as field conditions are suitable) may precede the warm weather problems; on the other hand, after the lagoon has worked all summer, the waste will be maximally stable, and fall land application may pose less overall odor problems (35).

Several different methods have been attempted to control odors arising from the lagoon, with varying degrees of success. A floating mat of biodegradable material, such as straw, permits some oxidation of the odorous gases before they reach the atmosphere; this approach may also reduce convection of gases to the atmosphere. A recent experimental approach to oxidation of the gases has been to aerate only the surface of the lagoon (9); this is discussed in more detail in the subsection entitled "Combined Aerobic-Anaerobic and Miscellaneous Treatment" (page VI-34). In the food industry, a plastic film covering the entire lagoon surface has been used to collect the evolved gases (principally methane), which are then flared off, eliminating most of the objectionable odors. Potentionally, the heat from the flare could be used to warm the influent to improve lagoon treatment efficiency. Chemical and enzymatic control of odors in lagoons have been unsuccessful, principally because of the variety of malodorous by-products and the imperfect natural mixing of the lagoons.

Unmixed effluent from anaerobic lagoons is low in suspended solids and hence can be irrigated. If solids are to be removed simultaneously by use of agitator and pump, the irrigation system must be designed for slurry handling (see the section on Liquid/Slurry Transport). Alternatively, the sludge, which is not offensively odorous, can be removed by dragline or solids handling machinery, depending on its moisture content; the ideal time for sludge removal is late fall, when the sludge is well-decomposed. If sufficient storage volume is available to maintain the design loading, sludge can accumulate for several years before this operation becomes necessary.

Anaerobic Digester. A third anaerobic storage/treatment which has been suggested for animal wastes is the anaerobic digester. In this component, the anaerobic waste degradation process takes place at a high rate due to controlled pH, temperature, dilution, and mixing.

An anaerobic digester is a closed vessel having either a fixed or floating cover. Waste addition, digested sludge removal, settled effluent removal, plus gas collection and recirculation are accomplished by means of an extensive piping system. Mixing can be done either by mechanical means or by release of compressed gas (35).

Major advantages of the anaerobic digester are:

1. The waste is stabilized rapidly with no odor release.
2. Methane (natural gas) is a useful by-product of the process.
3. There is no water pollution via seepage or overflow of the unit.
4. Its performance is less weather-dependent than that of other biological treatment components.

Important disadvantages are:

1. Little or no storage is provided by the digester unit. The products, effluent and sludge, must be stored or disposed of on land; the effluent is unsuitable for discharge to a watercourse without further treatment.
2. Capital costs are high; close process supervision by an experienced operator is required.
3. Mixing and pumping power requirements are significant.

Digester Design Parameters. Because of the above mentioned disadvantages, only laboratory scale anaerobic digester studies have been done. Loehr and Agnew (28) report successful operation with loading rates of from 0.1-0.4 lb. of total solids/ft.^{3}/day at an operating temperature of 35° C. (Beef wastes typically contain 9 lb. total solids/animal/day.) A dilution to 5 to 10 percent solids is necessary for complete mixing. Gas production (with heat value approximately 570 BTU/ft.^{3}) was measured at 8-9 ft.^{3}/lb. of volatile solids added; typical beef wastes contain 7 lb. volatile solids/animal/day (29).

Less efficiency may be expected in full-scale units due to incomplete mixing and lower operating temperatures.

Aerobic Storage/Treatment Components

Aerobic waste decomposition processes require the presence of gaseous free oxygen. The free oxygen content of water is minimal; therefore, in these processes it must be supplied through natural processes (photosynthesis, wind and wave action) or added by mechanical means.

Important characteristics of the aerobic decomposition process are:

1. In a properly designed and operated storage/treatment, the gases of decomposition are virtually odorless.
2. Some reduction in volatile solids is achieved, although less than that of anaerobic processes.
3. Aerobic decomposition processes are temperature dependent, with minimal biological activity below 40° F.
4. Pesticides, antibiotics, salts, and other residues are toxic to bacteria and will, in significant amounts, impair treatment efficiency.
5. Fertilizer value of aerobically decomposed waste is somewhat lower than that of similar fresh or anaerobically decomposed waste.
6. Land disposal is commonly practiced since effluents of aerobic treatment processes are too pollutionally potent for discharge to a watercourse.

Three aerobic components, naturally aerobic (oxidation) ponds, mechanically aerated lagoons, and oxidation ditches have been used to store/treat animal wastes.

Naturally Aerated (Oxidation) Ponds. If sufficient dissolved oxygen is present in the water of a waste storage impoundment, the decomposition process is aerobic. Since the supply of oxygen for quiescent ponds comes primarily from the atmosphere (photosynthesis of algae also plays a part), performance of this component is dependent on the surface area available for oxygen transfer; under appreciable waste loadings, aerobic conditions exist only near the surface.

The naturally aerobic pond has several important disadvantages:

1. The large surface area will often require extensive dike construction, with consequent high capital cost.

2. Extensive evaporation will occur from the pond surface, requiring a large water supply; the pond must also be sealed to prevent seepage loss and groundwater contamination.
3. Control of weeds and mosquitoes is usually necessary.

Because of these disadvantages, this system is not common in beef cattle waste management systems. In areas of high moisture deficit, a related option, the evaporation pond, is often used; see Section IV, "Evaporation Disposal" (page IV-23).

Design and Management. For beef cattle wastes, a design surface area of 1.5 ft.^{2}/pound of animal weight has been suggested for wastewater without prior solids separation; with removal of solids, this value may be halved (35). Depth must be limited to 3 to 4 feet to avoid oxygen depletion at the pond bottom. Good mixing and steady loading of the pond are necessary to prevent anaerobic conditions.

Mechanically Aerated Lagoons

A large volume storage for beef cattle wastewater is the mechanically aerated lagoon, a deep, well-mixed and oxygenated impoundment loaded by flushing or scraping.

Advantages of the aerated lagoon storage are:

1. With proper design and management, odor problems are minimal.
2. With long-term detention, an appreciable volatile solids reduction can be achieved.
3. With some maintenance, operation is largely automatic.

Disadvantages are:

1. power requirements (typically \$133/HP/year (38)) plus capital costs of aeration equipment,
2. large volume and aeration requirements for long-term detention,
3. possibility of biological upset and sensitivity to temperature variations, and
4. no discharge.

Effluent is normally disposed of on land by irrigation. Sludge may be suspended by mixing, then irrigated or spread on the land; alternatively, it may be dried and applied to the land with solids handling equipment.

Site Selection. In choosing a site for the aerated lagoon, essentially the same criteria apply as for the anaerobic lagoon (see subsection entitled "Anaerobic Lagoon Storage---Site Selection," page VI-16). Due to reduced odor potential, however, more flexibility in site choice is possible.

Aerated Lagoon and Aeration Design. Design of a mechanically aerated lagoon is somewhat similar to that of an anaerobic lagoon (see subsection entitled "Anaerobic Lagoon Storage--Sizing the Lagoon," page VI-17), with identical considerations of depth, side slopes, and solids removal. In this case, however, shape is dependent on the type, number, and configuration of the aerators, which perform the functions of mixing and oxygen transfer; a circular or square shape with rounded corners is usually chosen to prevent deposition of odor-producing sludge at points of minimum flow-rate. Because the oxygen transfer rate does not depend on surface area but on contact time with air bubbles, depths of 15 to 20 feet are commonly chosen (35).

A well-defined design procedure, based on known waste characteristics, has been developed for aerated lagoons (38). These characteristics, however, vary with the ration fed and hence must be evaluated by laboratory test. Empirical data suggest a simpler design procedure:

1. Estimate necessary liquid/slurry volume V_L as 0.75 ft.^{3} per pound of livestock (35):

   $V_L = N \times W \times 0.75$ ....EQN (VI-8)

   where: V_L = liquid/slurry volume, ft.^{3}
   N = number of animals
   W = average weight per head over the growing period, lb.

2. Estimate volume to be required for sludge storage over detention period. As a rough rule-of-thumb, 13 lb. volatile solids produce 1 ft.^{3} of aerobic sludge (a 900 lb. steer excretes 7 lb. volatile solids per day).

   $V_s = D \times N \times 7/13$ .... EQN (VI-9)

   where: V_s = storage volume of slurry, ft.^{3}
   D = detention time, days
   N = number of animals

3. Calculate total waste storage volume required:

   $V = V_L + V_S$ .... EQN (VI-10)

Additional storage for precipitation is allowed by incorporating at least a 2-foot freeboard in the design. Excavation volume can be calculated by using the procedure shown in the "Anaerobic Lagoon Storage--Sizing the Lagoon" subsection (page VI-17). The oxygen input rate should be based on laboratory measurement of biochemical oxygen demand (BOD) of the particular waste (38). From experience, however, an input rate of 2.0 pounds of oxygen per animal per day has been found to be satisfactory if the aerator is used year-round, 2.7 pounds if shut down from December through February. For partial odor control, an oxygen supply of 1.4 to 0.9 pounds may be sufficient (35); however, it is essential that the lagoon be well mixed.

Comparisons of aeration devices, typical efficiencies, advantages and disadvantages are given in Table VI-3.

Aerated Lagoon Management. The primary consideration in managing an aerated lagoon is the maintenance of aerobic conditions for odor control and the growth of aerobic microorganisms. For a properly designed system having sufficient aerator capacity, a major problem is that of loading the system continuously, i.e., furnishing a constant food

TABLE VI-3

CHARACTERISTICS OF AVAILABLE AERATION EQUIPMENT (38)

Equipment Type	Equipment Characteristics	Oxygen Transfer Efficiency (0_2 Transferred/0_2 Delivered)	Advantages	Disadvantages
Porous diffusers	Produce fine or small bubbles. Made of ceramic plates or tubes, plastic-wrapped or plastic-cloth tube or bag.	10-12%	High oxygen-transfer efficiency; good mixing; maintain high liquid temperature.	High initial and maintenance costs; tendency to clog; not suitable for complete mixing.
Nonporous diffusers	Made in nozzle, valve, orifice or shear types, they produce coarse or large bubbles. Some made of plastic with check-valve design.	4-8%	Nonclogging; maintain high liquid temperature; low maintenance cost.	High initial cost; low oxygen-transfer efficiency; high power cost.
Mechanical, surface-turbine	Low output speed. Large-dia. turbine, usually fixed-bridge or platform mounted. Used with gear reducer.	10-12%	Low initial and maintenance costs; high oxygen-transfer efficiency; tank-design flexibility.	Some icing in cold climates; more difficult to apply for total mixing.
Mechanical surface-propeller aerators	High output speed. Small-dia. propeller. They are direct, motor-driven units mounted on floating structure.	10%	Low initial cost; simple to install and operate; moderate transfer efficiency; adjust to varying water level.	Some icing in cold climates; poor maintenance accessibility.
Submerged-turbine or combination units	Units contain a low-speed turbine and provide compressed air on sprage ring. Fixed-bridge application.	---	Complete mixing; high-capacity input per unit volume; deep-tank application; moderate efficiency; wide oxygen-input range.	Require both gear reducer and compressor; tendency to foam; high total-power requirements.

supply to the microorganisms. The addition of large amounts of waste in a short period can inhibit the aerobic decomposition process and result in the growth of anaerobic bacteria, with attendant odor problems. Once the system is upset, a considerable period of time at reduced loading is needed to regain steady-state conditions (35).

To avoid these problems, daily flushing or scraping of the housing facility is necessary. For economical use of fresh water, flushing water may be drawn from the lagoon. To minimize maintenance, drainage to the impoundment should be by gravity through unobstructed channels. Alternatively, a less desirable solution is to have all drainage to a centrally-located sump, where a chopper-type sludge pump is used to transfer the waste to the lagoon.

A second consideration is the effect of cold weather on the system. Below 40° F, microbial action is retarded to such an extent that aeration serves little purpose. As warm weather approaches, however, the aerator should be restarted. Because of the backlog of unstablized waste accumulated during the winter, it may take some time for steady-state aerobic conditions to be achieved; hence, some odor problems during this period may be anticipated.

After some time, sludge accumulation will have reduced the lagoon volume below the design level, necessitating cleanout. The ideal time for this operation is late fall, when the lagoon is well aerated and the solids are maximally stabilized. The same type of equipment can be used as that used to empty anaerobic holding tanks: an auger or high-volume pump for stirring the sludge from the bottom and entraining it in the liquid, followed by irrigation or tank wagon field disposal. A buildup of excess water in the lagoon can be disposed of in the same manner.

Oxidation Ditch

Aerobic stabilization of waste has the critical advantage of reducing or eliminating objectionable odors; primarily for this reason, extensive research has been done on the performance of the oxidation ditch in confinement housing operations.

An exploded-view perspective sketch of an oxidation ditch is shown in Figure VI-4. The two principal components are the oval shaped open-channel ditch and the stationary aeration rotor which supplies oxygen and circulates the ditch contents to keep the solids in suspension. In operation, raw wastes are continuously added to the ditch and diluted by the ditch contents; due to the large volume of oxygen supplied by the rotor, aerobic bacteria break down the degradable waste into stable material, with carbon dioxide and water as the principal by-products. The ditch can be operated either on a batch or continuous basis, with overflow to a quiescent settling basin where the solid sludge settles out and the clarified liquid typically passes on to a storage lagoon. In addition to odor control, the principal advantages of the oxidation ditch are:

1. It is ideally adapted to confinement housing systems, in that it can be installed directly beneath a slotted floor.
2. A properly designed and operated system is remarkably stable, requiring nominal attention and maintenance.
3. Under certain conditions (17), a considerable reduction in nitrogen occurs, making heavier land application rates possible without crop damage.

Principal disadvantages are:

1. Capital and operating costs, although reasonable, are significant.
2. The ditch does not, in itself, provide much storage capacity nor is its effluent suitable for discharge to a watercourse.

In mild climates, the oxidation ditch can also be operated outside the confinement building, with loading by means of scraping. Periodic cleanout and disposal of sludge, either as mixed liquor (slurry) or as solids, is necessary. Currently, the value of the sludge as an animal feed ingredient is being investigated by researchers (24).

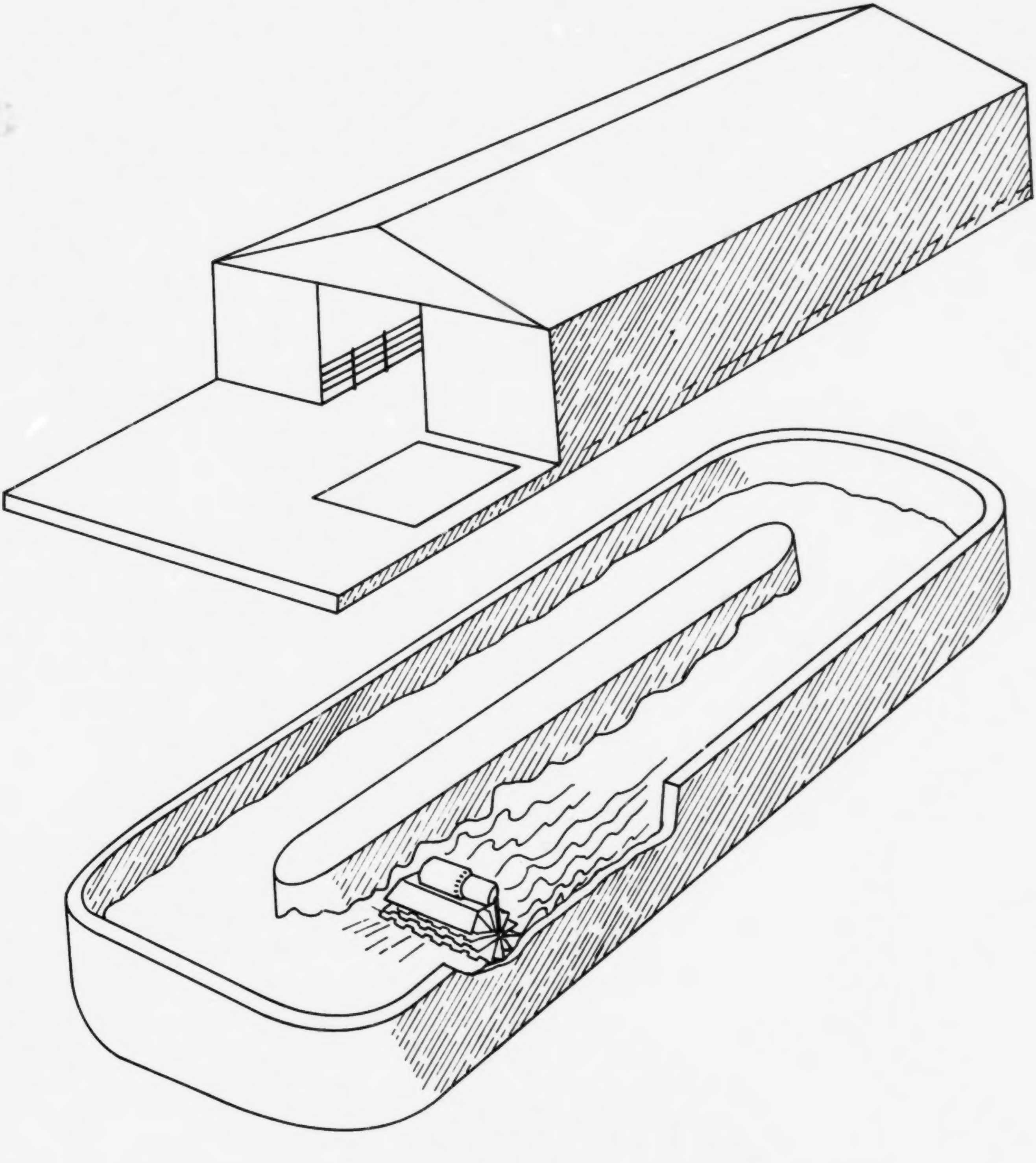

FIGURE VI-4. EXPLODED VIEW OF CONFINEMENT BUILDING AND OXIDATION DITCH.

Oxidation Ditch Design. Volume of the oxidation ditch is based on the waste loading and 30 ft.^{3} per pound of daily BOD_5 has been recommended (35); on this basis, a 900 pound beef animal, for which daily BOD_5 has been found to be 1.35 pounds, would require approximately 40 ft.^{3} of liquid volume. A more exact BOD_5 can be measured by laboratory tests on the individual waste.

Dimensions of the ditch are somewhat adaptable to the design of the confinement building. For example, the ditch may make multiple passes down the length of a wide building, rather than taking the conventional oval racetrack shape. However, the following constraints also apply:

1. Rotors are presently available in nominal 3, 6, and 8 foot lengths; channel width can be approximately one-fifth greater than rotor length.
2. Distance between rotors should be limited to a maximum of 300 feet.
3. To maintain adequate velocity and prevent solids settling, channel depth is limited to approximately 18 inches.

Construction of oxidation ditches is not limited to new housing facilities. Subject to these constraints, the structure can, for instance, replace a shallow pit located beneath a slotted floor simply by rounding the corners of the pit and incorporating a center island. In any installation, however, it is important to round the corners smoothly and to eliminate any dead spots which might lead to sludge deposition.

A variety of rotor designs have been examined for mixing ability and oxygen transfer efficiency. To prevent solids deposition in the ditch, the rotor must provide a minimum 1 ft./second slurry velocity; approximately 2.7 lb. of oxygen transfer per animal per day is needed to maintain aerobic conditions. The corresponding power requirement is on the order of 1.42 KWH/animal/day (35).

There are two methods of unloading the ditch. First, if sufficient volume is available, the rotor can be adjusted as the level of the ditch fluctuates due to addition of raw wastes; batches of the mixed liquor are removed periodically for storage or disposal. Secondly, a continuous overflow to a lagoon or holding tank can be achieved with a diversion channel leading away from the oval. This alternative, which requires less supervision, is the more popular.

Oxidation Ditch Management. For a slotted floor confinement building, the startup procedure for the continuous overflow system is as follows:

1. The ditch is filled with fresh water to the volume calculated from the BOD loading.
2. The rotor is adjusted to the desired immersion depth (usually 4 to 6 inches); because the level of the ditch remains constant, no further adjustment is required.
3. The rotor is started and animals are brought into the building. To allow the bacterial population to adjust, a gradual increase in animal density is suggested.
4. A close surveillance of the ditch is maintained. A buildup of foam, an indicator of anaerobic conditions, can be countered by adding a quart or two of crankcase oil; further increases in animal density should be suspended until the foam subsides.
5. When the ditch approaches steady-state operation, the animal population should be kept constant and the rotor kept in operation until system shutdown.

In general, steady-state oxidation ditch operation is trouble-free. However, there are several potential trouble spots which should periodically be checked. The oxidation ditch is an aerobic system which should exhibit very little odor; if a "septic tank" or strong ammonia odor begins to develop, the ditch is becoming anaerobic. This condition can arise in three ways: (a) a sludge accumulation in the bottom of the ditch,

(b) insufficient oxygen supplied by the rotor, or (c) biological upset of the bacteria. The first condition can occur even in a well-designed ditch over a long period of time, but is more often due to insufficient velocity or rough spots in the channel. By dilution with fresh water, the accumulation can be washed away while the ditch remains in operation. However, if the cause of the deposition is apparent, it should be corrected.

Combined Aerobic-Anaerobic and Miscellaneous Treatment

In addition to the single-component storage/treatment processes elaborated in the two prior subsections, several combined anaerobic-aerobic treatments have been investigated for possible application. These alternatives are aimed at modifying the waste for reuse or facilitating disposal. Some objectives of combined treatment processes are listed:

1. upgrading of the liquid to a quality suitable for discharge to a watercourse (this objective involves primarily reduction of organic material (BOD) and suspended solids, although ammonia, phosphates, salts, etc. may also be important);
2. upgrading the liquid for purposes of flushing (important parameters are total solids, odor, and possibly color);
3. upgrading the liquid for reuse as drinking water (this requires removal of essentially all of the above-mentioned impurities, plus nitrates, and pathogenic microorganisms);
4. modification of the waste for land disposal (often nitrogen and salts are the nutrients which limit application rate to the soil; its reduction permits disposal on smaller land areas);
5. modification of the solids fraction for refeeding to animals (in this case, nitrates, odor, and pathogens, as well as feed value, are important); and
6. improved waste storage characteristics.

In the following paragraphs, selected and combined handling and miscellaneous processes having possible application to these objectives are discussed.

Anaerobic and Aerated Lagoons. By sequencing an anaerobic with an aerobic treatment process, it has been suggested that the final effluent of an animal waste treatment system may be made suitable for discharge to a watercourse. An embodiment of this idea, a single anaerobic lagoon followed by one or more aerobic lagoons, has been accepted as a standard treatment process by the meat processing industry. By the use of this system, extremely low levels of BOD, a major waste strength parameter, have been achieved. One such system, an anaerobic lagoon followed by two aerated lagoons, is presently being used in Florida (39) to treat dairy cattle wastes. Preliminary performance figures (Table VI-4) indicate a final effluent having a quality nearly suitable for discharge (20 mg/l of BOD_5 and 20 mg/l of suspended solids is presently a common standard). Detention times are calculated from the storage volume of the lagoons and a mass balance for the system.

TABLE VI-4

PERFORMANCE OF ANAEROBIC-AEROBIC LAGOON SYSTEM (39)

Sample Source	BOD_5 (ppm)	TSS^1 (ppm)	DT^2 (days)
Anaerobic Lagoon Influent	661	611	
Anaerobic Lagoon Effluent	77	102	22.1
First Aerobic Lagoon Effluent	31	66	8.6
Second Aerobic Lagoon Effluent	24	81	15.5

[1] TSS = Total Suspended Solids

[2] DT = Detention Time

For comparison, fresh beef wastes have been found to have a BOD_5 of 16,000 mg/l. Thus, to obtain a comparable influent waste strength would require a dilution of greater than 24:1. This figure, plus the long detention times required even in a mild climate, indicates that the system is not feasible for large beef waste treatment facilities.

Anaerobic Lagoon with Aerated Surface. As noted in the subsection on anaerobic systems (page VI -7), their primary problem is that of odor production; on the other hand, maximum nutrient value is preserved. Aerobic systems are generally free of noxious odors but may incur significant aeration costs.

To exploit the best features of both systems, an experimental dairy-waste storage/treatment was designed by Barth and Polkowski (9) incorporating a 20 to 24 inch aerated layer of wastewater over an otherwise anaerobic lagoon. Effluent from the surface layer was used for flushing. A dilution of 2:1 was found to be satisfactory. Odor levels were much lower than those of totally anaerobic lagoons.

Based on limited laboratory sized test units, the following advantages were noted:

1. Low volume surface aeration effectively reduced odor intensity and surface scum.
2. Nutrient recovery was high.
3. Lagoon construction was much cheaper per unit of storage volume than was tank storage construction.
4. Effluent quality from the aerated layer was suitable for flushing.

Although this component shows promise for odor control and production of a suitable effluent for flushing systems, the effluent has been shown not suitable for discharge. Full-scale systems are needed to demonstrate its feasibility.

Barriered Landscape Water Renovation System (BLWRS). A new concept in liquid waste treatment is being developed by Erickson et al. (18). This concept is called the Barriered Landscape Water Renovation System (BLWRS);

a cross-sectional schematic view of a prototype unit, with typical dimensions, is shown in Figure VI-5.

In this system, a water-impermeable barrier, such as plastic film, is buried horizontally in a light-to-medium textured soil. Similar soil is mounded on top of the original surface, with the subsurface barrier extending some distance beyond the edges of the mound. On top of the mound is a thin layer of limestone or slag.

In operation, an irrigation system distributes wastewater having a limited amount of solids uniformly over the surface of the mound. Solids are filtered out on the surface and decompose there, with nutrients either infiltrating into the mound or fertilizing surface vegetation. Wastewater percolates through the limestone layer, which efficiently adsorbs phosphates, and passes into the aerobic soil mound. Below the mound, the liquid is forced by the barrier to move laterally to its edge into drainage tile due to its saturated condition, the soil immediately above the barrier is anaerobic. If sufficient detention time is given the liquid and enough food energy is available in the anaerobic zone, soil microorganisms in the aerobic-anaerobic sequence transform other forms of nitrogen to atmospheric nitrogen gas; these parameters depend upon system design. The effluent can be reused for flushing or may, in the future, prove suitable for discharge or other use.

Performance of the system on liquid flushed from a dairy cattle holding pen is shown in Table VI-5; to avoid clogging the soil surface, solids were screened from the wastewater prior to irrigation and field spread by tank wagon. Average effluent wastewater parameter values, with the exception of nitrate nitrogen, show excellent treatment; improved design may reduce the nitrate value as well.

Problems noted with the prototype system were:

1. some reduction in soil infiltration rate due to solids buildup, and
2. freezing during extreme winter weather.

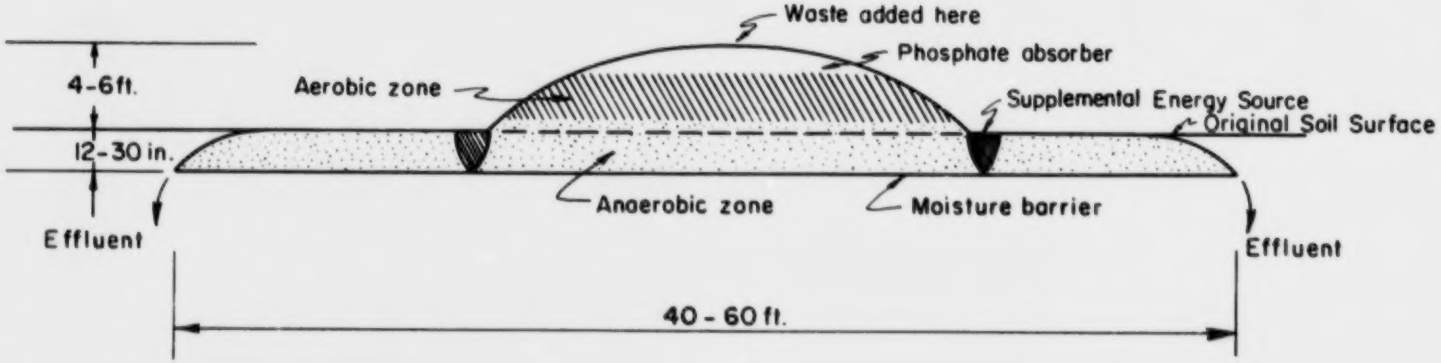
Waste added here
Phosphate absorber
Aerobic zone
Supplemental Energy Source
Original Soil Surface
4-6ft.
12-30 in.
Anaerobic zone
Moisture barrier
Effluent
Effluent
40 - 60 ft.

FIGURE VI-5. SCHEMATIC CROSS-SECTION OF BLWRS.

Research designed to overcome these problems and improve system performance is continuing.

TABLE VI-5

AVERAGE DAIRY CATTLE WASTEWATER
PARAMETER VALUES FOR THE BLWRS (18)

Parameter	Waste, mg/l	Effluent, mg/l
Org N + NH_3-N	300	3
NO_3-N	10	10
PO_4-P	40	0.02
BOD	1200	5

Spray Runoff System. A relatively new treatment, possibly applicable to upgrading of liquid wastewater quality for flushing, is the Spray Runoff System. Process details and performance on feedlot rainfall runoff are given in Section IV, "Spray Runoff System."

Solids Separation

In waste management systems, handling or unit treatment process efficiency can often be substantially increased by separation of a portion of the waste solids. Liquid-solid separation unit operations for liquids and slurries are considered in this section; drying, which is ordinarily economically feasible only at low initial moisture contents, is discussed in Section V, "Solid Wastes Control" (page V-1). Settling basins and porous dams for preliminary solids separation of feedlot runoff are presented in Section IV, "Runoff Carried Wastes" (page IV-1).

Free Drainage. Because of the cellular structure of cattle feces, only approximately 4 percent moisture can be removed by free drainage from fresh waste having an initial moisture content of 85 percent, wet basis (5). The liquid fraction retains a significant pollution potential and is not suitable for discharge to a watercourse without treatment. Addition of aluminum chlorohydrate has been used to improve process efficiency (29); the filtrate, however, contained a higher percentage of suspended solids. Free drainage requires a large surface area (as on a sand filter) or long detention times; equipment for distribution and collection is also necessary.

Stationary Screen. A useful separation device currently finding wide application in processing industries is the stationary screen (Figure VI-6). In this unit, the slurry passes into a headbox and over a weir, then flows evenly down an inclined screen. Because of a particular screen shape and configuration, liquid is stripped from the solids and passes through the screen; solids are collected at the base of the screen.

This component is constructed of stainless steel and/or fiberglass for corrosion resistance. It has no moving parts, can handle wide variations in slurry total solids and flow rate, and is virtually maintenance-free. In tests on beef cattle wastes, a maximum total solids content of 18 percent was achieved (5).

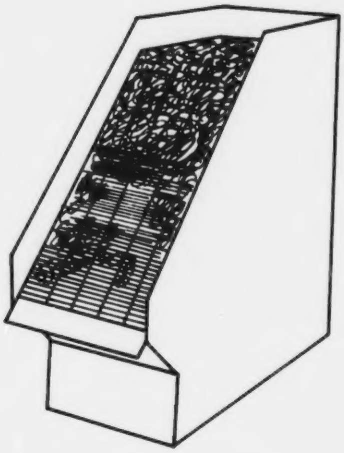

FIGURE VI-6. STATIONARY SCREEN.

Vibrating Screen. Extensive testing of the performance of a vibrating screen separator on beef cattle wastes was done by Ngoddy et al. (37). This device, shown in Figure VI-7, utilized a rotating, shaking action of the screen to separate solids and liquids into two streams. The machine is simple to operate, requires little maintenance, and can handle variations in flow and solids content. The solids fraction obtained using 60 to 120 mesh screens varied from 70 to 80 percent, wet basis, while the effluent averaged approximately 6 percent total solids. The solids had a friable, non-clumping structure, were odor-free, and did not attract flies.

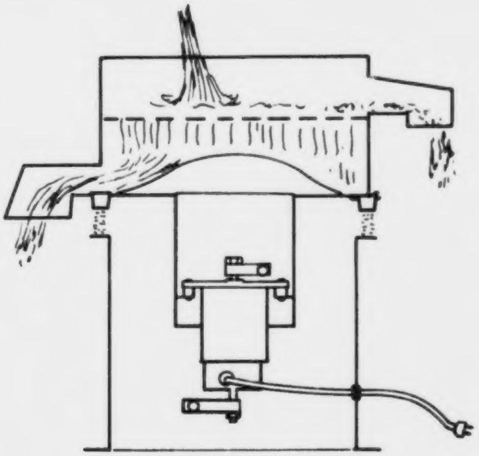

FIGURE VI-7. VIBRATING SCREEN, CROSS-SECTIONAL VIEW.

Other Mechanical Devices. Several other mechanical solids-liquid separation devices are commonly used in various industries. Glerum et al. (21) report excellent performance on swine wastes from an inexpensive centrifugal separator used in the potato starch industry.

Other devices, such as the decanter centrifuge, which may achieve higher solids separation, have been found to be unsuitable due to high capital cost, need for constant supervision, or high maintenance requirements. Performance of selected units on beef cattle wastes are given in Table VI-6.

TABLE VI-6

SOLIDS/LIQUID SEPARATION EFFICIENCIES OF SELECTED MACHINES (5)

Machine	Maximum Total Solids, %
Vacuum Filter	23
Three-roll Mill	37
Screw Press	38

Chemical Treatment. In some cases, efficient liquid/solids separation can be achieved by chemical treatment. Suspended solids, due to chemical attraction, form flocs which settle or float, leaving a relatively clear liquid.

Ngoddy et al. (37) examined the use of several chemical flocculants on beef cattle wastewater, including ferric chloride and anionic, cationic, and nonionic polyelectrolytes, with and without pH adjustment. Although several of these were effective in concentrating solids, each formed an ill-smelling sludge, deemed a serious nuisance; moreover, chemical costs were considered excessive for livestock enterprises.

Liquid-Slurry Transport

Two options for transport and land disposal of liquid-slurry wastes are presently in use: (a) pumping from storage to a spreader vehicle which is then pulled or driven to the field, and (b) irrigation of the liquid-slurry through conventional or modified water irrigation systems. Tables VI-7 and VI-8 are useful in choosing and sizing a land disposal

TABLE VI-7

IRRIGATION FACTORS FOR LIQUID/SLURRY WASTES (42)

		Number of Days (10 hours/day) Required to Dispose of a Given Quantity of Liquid Wastes							
		Acre-Inches of Waste							
Gallons Per Minute	Acre-Inch Per Hour	6	12	24	36	48	60	120	240
25	0.05	12.0	24.0	48.0					
50	0.11	5.5	10.9	21.8	32.8	43.6	54.6		
100	0.22	2.7	5.5	10.9	16.4	21.8	27.3	54.5	
200	0.44	1.4	2.7	5.5	8.2	10.9	13.6	27.3	54.5
300	0.66		1.8	3.6	5.5	7.3	9.1	18.2	36.4
400	0.88			2.7	4.0	5.5	6.8	13.6	27.4
500	1.10			2.2	3.2	4.4	5.5	10.9	21.8
600	1.32			1.8	2.6	3.6	4.6	9.1	18.1
800	1.77				2.0	2.7	3.4	6.8	13.6
1000	2.21					2.2	2.7	5.4	10.8

UNITS--

1 acre-inch = 27,154 gallons = 3,621 cu. ft.
1 acre-foot = 12 acre-inches = 325,848 gallons = 43,560 cu. ft.
1 acre-inch/hour = 450 gallons/minute = 1 cubic foot/second

system. Other methods of disposal, destruction, or reuse primarily rely on pumping for liquid-slurry transport within their respective processing operations.

Spreader System. Three methods are used for movement of the slurry from storage to the tank of the spreader vehicle: pressure pumps, vacuum pumps, and augers. Pressure pumps are either of the chopper impeller (modified centrifugal) type, which comminutes the fibrous material, or the diaphragm type, in which no moving parts are exposed to the corrosive slurry. Of the two, the centrifugal pump is higher in capacity, yet, lower in cost and efficiency. Pressure pumps fall into two major classifications:

1. electric-powered pumps of 5 hp or less which have a capacity of 200 to 400 gallons per minute, depending on the condition of the slurry and the slurry head, and require separate agitator for the storage; and
2. tractor-powered pumps of 25 to 50 hp with a capacity of 1400 to 2500 gallons per minute which also serve as agitators.

A second method is the tractor-powered vacuum pump mounted on the spreader vehicle. Delivery rate depends largely on the dilution of the slurry; a separate agitator is required for most storage tanks. Finally, special slurry auger conveyors having heavy-duty tubing coupled with standard flighting have been used. Delivery rate per horsepower is lower than that for the centrifugal pump and high maintenance requirements are anticipated. At least a 6-inch diameter auger is necessary; horsepower required is proportional to auger length.

Spreaders range from 750 to 2500 gallons in capacity. These are equipped with wide floatation tires to minimize soil compaction. On some machines, an internal agitator is employed to reduce plugging and improve uniformity of delivery. Most tanks empty by gravity (vacuum tanks pressurize the slurry) onto a spinning spreader disc driven by a small hydraulic motor; spreader swath varies from 10 to 30 feet.

Several machines have been developed for immediate incorporation of the slurry into the soil, either by injection or by dispensing the fluid into a furrow which is then immediately covered (10, 52). Chief advantages of these are: (a) minimization of fly and odor problems, (b) elimination of water pollution by runoff, and (c) retention of maximum nutrient value. Disadvantages are: (a) higher horsepower requirements and (b) lower rates of machine travel.

Irrigation Systems. Several types of liquid/slurry irrigation systems have been used for transport and disposal of beef feedlot wastes; a comparison of systems based on various factors is given in Table VI-8. Liquid/slurry total solids concentrations up to 5 percent can be handled by any of these irrigation methods, depending on the other factors listed; above 5 percent, however, only the manure gun has been shown to be satisfactory. The upper limit for the manure gun is approximately 15 percent total solids (14).

There is a great difference between design of a conventional sprinkler irrigation system (as for feedlot runoff; see Section IV, "Runoff Carried Wastes" (page IV-1) and design of a system for pumping thick slurries. When the solids content of the waste is 5 percent or less, pumped cattle wastes have flow properties somewhat similar to those of water (27); however, when the solids content is above 5 percent, the consistency is that of ketchup, which requires agitation before it will flow. Pressure drops in slurry irrigation systems vary, based on solids content, between values less than and greater than that of water. Corrosion and abrasion are important factors. Finally, solids will plug the pipeline if some minimum fluid velocity is not maintained.

For good design, it is essential that the properties of the slurry be known (these depend largely on the feed ration and storage/treatment history of the waste). A complete discussion of slurry property measurement and application of theory to design is beyond the scope

TABLE VI-8

LIQUID/SLURRY WASTE DISPOSAL SYSTEM SELECTION (42)

	Type of System										
	Tank Wagon	Sprinkler								Gravity	
Factor Considered	Honey Wagon	Hand-Carry Sprinkler	Traveling Gun	Towline	Manure Gun	Solid Set	Side Roll	Boom	Center Pivot	Gated Pipe	Open Ditch
Soil Type	Suitable for use on soils with a wide range of intake rates								Moderate to high intake soils	Soils with moderate to low intake rates	
Surface Topography	Adaptable to a wide range of surface topography						Limited to moderately undulating topography		Wide range	Limited to moderate to flat slopes	
Labor Required	Very High on large operations	High	Low	Moderately low	High on large operations	Very low	Moderate		Very low	High	Very high
Management required 1)	Low	Moderately Low			Moderately Low					High	Very high
Flexibility for Expansion	Inflexible 3)	Moderate	Inflexible 3)	Moderate		Inflexible 3)	Moderate	Inflexible 3)	Inflexible 3)	Very flexible	
Initial Investment	Low to Moderate		Moderate	Low to Moderate		Highest	Low to Moderate		High	Low to Moderate	Lowest
Operating Costs2)	Moderate to High		High	Moderate to High						Low	
Crop Suitability	All except tall growing crops	All	All with Adaptations				All except tall growing crops	All		All	
Size of Operation	Small to Medium Size		All Sizes		Small to medium size		All Sizes		Large	All sizes; depends on topography	
Type of Effluent	Liquids to semi-liquid slurries	Liquids only	Liquids to semi-liquid slurries	Liquids only	Liquids to semi-liquid slurries		Liquids only		Well filtered liquids	Liquids only	

Note: 1) Management refers to the skill required, or the ability to set the system and go off and leave it.
2) Operating costs are a small factor in selecting a waste disposal system.
3) Of course, another system may be purchased.

of the manual; however, a preliminary check on the adequacy of a system design can be made with the information given below and in Section IV, "Runoff Carried Wastes" (page IV-1).

Design Considerations. There are three major differences in the design of slurry pumping systems and conventional irrigation systems: (a) choice of pump to handle the slurry, (b) calculation of friction head loss through pipe and fittings, and (c) estimation of minimum velocity needed to prevent deposition of solids in the pipe. Only limited research on pumping of animal waste slurries has been reported. The following discussion is based upon research of pumping characteristics of dairy cattle wastes; because these are generally higher in fiber content than those of beef cattle, use of these data should result in a conservative system design.

Choice of Pump. Both centrifugal and positive displacement pumps are in common use for pumping slurries. Centrifugal pumps are characterizied by high capacity but low efficiency; these are unsuitable for high-pressure delivery requirements (for cost-capacity data, see Section VII, Table VII-2, Liquid/Slurry Wastes Handling Equipment). Positive displacement pumps are comparatively low volume, high pressure, high efficiency units higher in cost and maintenance.

A third category, the advancing cavity (i.e., helical type) pump, has been found to have favorable characteristics of both of the other types. A comparison of typical pumping characteristics for all three types is given in Figures VI-8, VI-9, and VI-10. Additional tests are reported by Hart et al. (22), who suggested that centrifugal pumps be used only for slurries having less than 4 percent total solids; Staley et al. (49) recommend a maximum of 8 percent total solids for the helical pump.

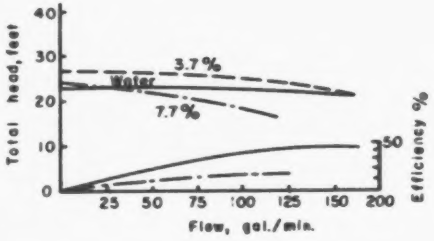

FIGURE VI-8.

CENTRIFUGAL (CHOPPER TYPE) SLURRY PUMP CHARACTERISTICS (22).

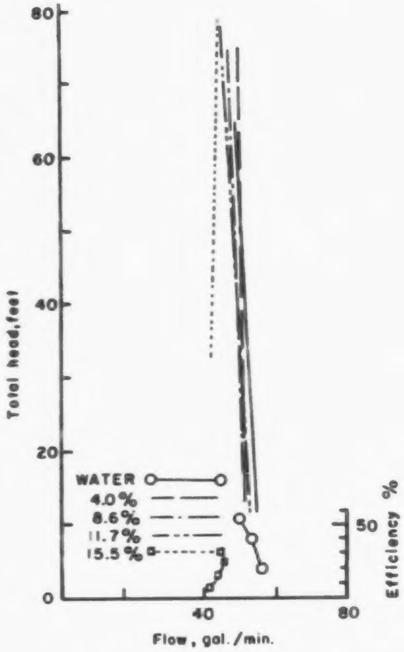

FIGURE VI-9.

ADVANCING CAVITY (HELICAL) SLURRY PUMP CHARACTERISTICS.

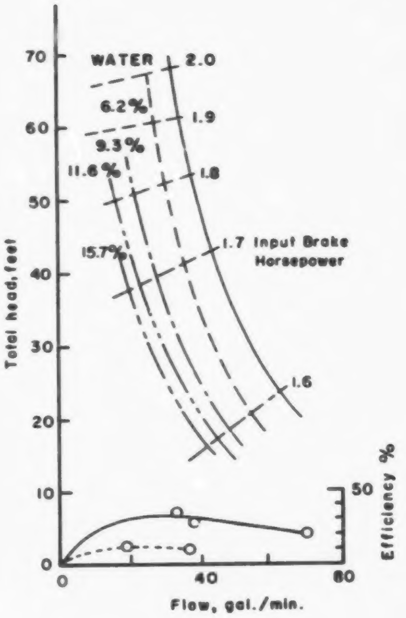

FIGURE VI-10.

POSITIVE DISPLACEMENT SLURRY PUMP CHARACTERISTICS.

Estimation of Deposition Velocity. The minimum permissible velocity in the pipeline depends on the pipe diameter, solids concentration, and particle density. This critical velocity can be estimated as follows:

1. Measure or select the volume solids concentration to be used in the slurry.
2. Select a trial pipe size, based on the design flow rate for the system and calculate the corresponding velocity. Three or 4-inch mains with 3-inch laterals have been suggested as a compromise between cost and friction resistance (49).
3. From Figure VI-11, read the value for F based on the volume concentration of solids.
4. Calculate the critical deposition velocity:

   $$V_d = F\sqrt{32.2D} \quad \text{EQN (VI-11)}$$

   where: V_d = critical velocity, ft./sec.
   F = factor read from Figure VI-11
   D = inside pipe diameter, ft.
5. The chosen design velocity should be at least 1 ft./sec. greater than the critical deposition velocity. If it is not, the pipe diameter can be rechosen.

Example: A manure slurry having a solids concentration of 4 percent by volume is to be pumped at a rate of 100 gal./min. (0.2228 ft.^{3}/sec.). A 4-inch main has been chosen. Check the velocity to see if deposition will occur.

The trial velocity in the main is calculated by:

$$V = Q/A \quad \text{EQN (VI-12)}$$

where: V = average cross-sectional pipe velocity, ft./sec.
A = cross-sectional area of pipe, ft.^{2}
Q = flow rate, ft.^{3}/sec.

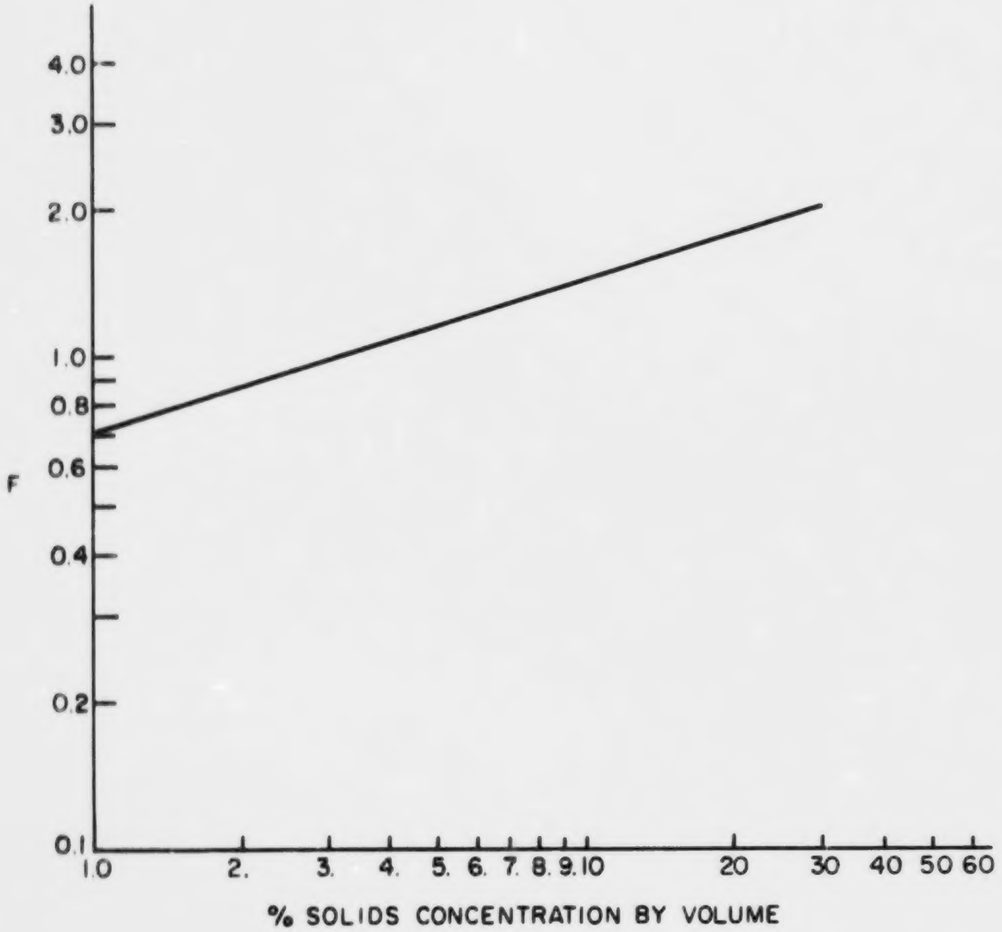

FIGURE VI-11. SOLIDS DEPOSITION FACTOR.

Then: $V = \frac{0.2228}{\pi(2/12)^2} = 2.56$ ft./sec.

From Figure VI-11, using a 4 percent solids concentration, F is read as 1.07. Substituting in Equation (VI-11),

$$V_d = 1.07\sqrt{32.2\ (4/12)} = 3.50 \text{ ft./sec.}$$

The 4-inch main is too large. A smaller pipe is needed for the 100 gpm flow rate. Calculating again, using 3-inch pipe:

$$V = \frac{0.2228}{\pi(1.5/12)^2} = 4.54 \text{ ft./sec.}$$

This pipe has a flow rate over 1 ft./sec. greater than the critical deposition velocity; hence, no solids buildup is anticipated.

Calculation of Friction Head Loss. A major difficulty in designing slurry pipeline systems is the lack of information available on friction head loss through pipes and fittings. Figure VI-13, based on pumping tests of dairy cattle manure slurries through aluminum pipe, illustrates the variation in pressure drop which occurs with dilution (49); this behavior is typical of manure slurries (22). At low total solids content, friction loss is less than that of water; at higher concentrations, it becomes much greater.

A rule-of-thumb which has been used for slurry irrigation design is to use the published pressure drop data for water flow through pipes and add 10 percent to these figures (19). Figure VI-13 illustrates that this is an oversimplification, leading to overdesign at low solids concentrations and underdesign at high values of total solids.

In the absence of better data, Figures VI-12 and VI-13 may be used for preliminary design. Typical elbow losses for aluminum pipe were given by Staley et al. (49) as 50 to 80 feet equivalent length of 2-inch diameter pipe at 2 percent total solids and 200 to 210 feet equivalent length of 3-inch pipe at 9 percent total solids. A complete design procedure, based on measured slurry properties, is given by Aude et al. (8).

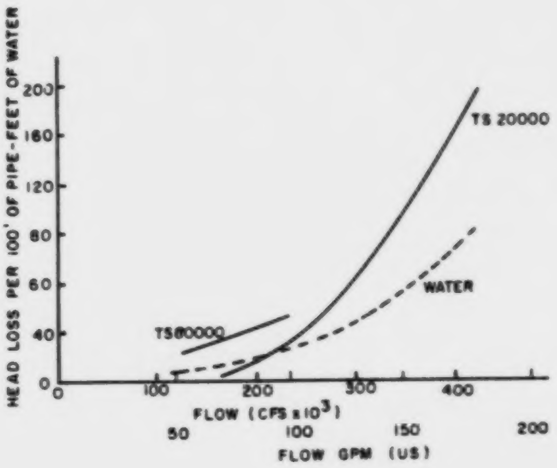

FIGURE VI-12. PRESSURE DROP OF MANURE SLURRY THROUGH A 2-INCH PIPE (49).

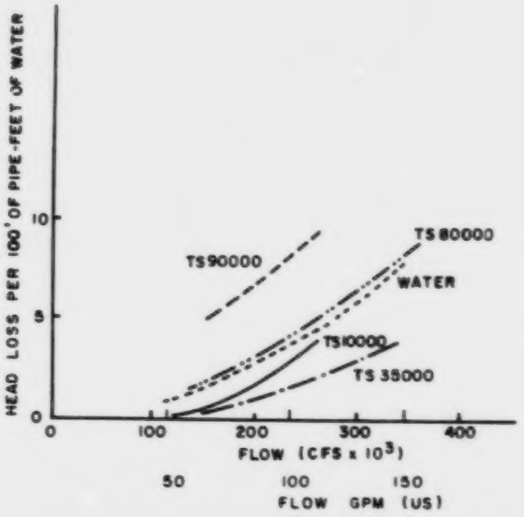

FIGURE VI-13. PRESSURE DROP OF MANURE SLURRY THROUGH A 3-INCH PIPE (49).

Management Considerations. System components for transport of animal waste slurries are similar to those used in conventional piping systems; however, some additional precautions are warranted. Manure slurries are extremely corrosive and somewhat abrasive, due to the presence of grain and grit particles. Thus, protective oxides which build up by corrosion may be scoured from the surface, greatly decreasing pipe life. Limiting pipeline velocities to less than 7 ft./sec. can largely reduce abrasion. Flushing pipelines with water following irrigation retards corrosion, reduces odor, and helps to eliminate plugging problems due to solids deposits. Choice of long-radius elbows and full-flow valves, along with elimination of dead ends, can eliminate plugging; however, it is advisable to provide easy access to all parts of the system in case plugging develops.

Little information has been published on sprinkler types and spacings. A riser-mounted 7/8" diameter rubber sprinkler nozzle delivering 167 to 208 gpm had a maximum wetted radius of 110 feet at 3 to 5 percent total solids (47); a 9 percent total solids slurry discharged through a 1-7/8" diameter manure gun had a uniform distribution radius of 100 feet (53). For additional information, consult manufacturers' literature.

Disposal, Destruction, and Reuse of Liquid/Slurry Wastes

Manure liquid/slurry wastes can be viewed in two ways by the feedlot management: first, as a resource to be used as efficiently as possible to defray costs of storage, treatment, and handling; second, as a material to be destroyed or otherwise disposed of in the most expedient manner, consistent with pollution and other constraints. Either approach will require careful management.

Several alternatives have been or are being considered: wet oxidation (destruction), refeeding, fuel production, use as a fertilizer, and land spreading for disposal only. Of these, the wet oxidation process (32) is considered too expensive and sophisticated for feedlot use; fuel production processes use only the solids fraction and are unproven (7) and refeeding of wastes has yet to be approved (51). The two remaining alternatives involve land application.

Land Application. Waste application to the land affects the soil environment and its vegetation physically, chemically, and biologically. A summary of potentially deleterious effects of slurry application upon soil characteristics (the extent depending on rate and timing of application) is listed (12):

1. Heavy accumulations of organic material can fill the soil pores, decreasing the infiltration rate into the soil profile.
2. Plugging of soil pores can reduce the supply of atmospheric oxygen to the soil and create anaerobic conditions.
3. Soil structure (tilth) can be destroyed by heavy liquid application.
4. The beneficial earthworm population of the soil can be destroyed.

Adverse effects on vegetation may include:

1. retardation of growth due to waste matter buildup on leaves,
2. nitrogen burn,
3. buildup of toxic materials in the root zone,
4. crowding out of desirable plants by weed growth, and
5. buildup of animal-toxic nitrates in forage.

In addition, land application of slurries can potentially lead to nitrate pollution of groundwater, pollution of surface water through runoff, and air pollution. For these reasons, it is apparent that careful management is needed to minimize damage from slurry application. On the other hand, land disposal of liquid/slurry wastes is the most economical alternative available; furthermore, these wastes can provide a significant fraction of plant nutrients.

Application Rates for Slurry Wastes. An attempt to estimate the rate at which liquid/slurry wastes may be applied to the land without damage suggests that a number of factors be considered:

1. the soil, its fertility, and hydraulic properties;
2. the vegetation, its nutrient requirements, susceptibility to toxicity or nutrient imbalance, moisture requirements, production per unit land area, and commercial value;
3. the nutrient value of the fresh waste, type and amount of plant-toxic components, prior storage/treatment, and dilution; and
4. climatic factors of precipitation, evaporation, and temperature.

At the present time, many of these data are unavailable or uncorrelated; however, some guidelines are available. Table VI-9 gives the results of several analyses of fresh beef wastes. From these data, the potential nutrient value and sodium concentration may be estimated.

Nutrient availability can be dramatically affected by treatment/storage. Under most circumstances, either nitrogen or sodium concentration limits the waste application rate (the nitrogen content can be appreciably reduced by some storage/treatment, notably the BLWRS and oxidation ditch). Table VI-10 gives the percentage of beef cattle waste nutrients utilized by corn as a function of treatment/storage.

TABLE VI-9

TYPICAL VALUES OF BEEF WASTES PARAMETERS (37)

Parameter	Value
Total Solids	4.9 - 9.5 LB/Day
N	3.1 - 9.8% Total Solids
P	1.35 - 1.7% Total Solids
K	2.27 - 3.0% Total Solids
Na*	0.09% Total Solids

*May be as high as 1%, Depending on Ration.

TABLE VI-10

EFFECT OF TREATMENT/STORAGE ON NUTRIENT RECOVERY* BY CORN CROP (23)

Type of manure handling	Yield g per pot	Recovery by crop N percent	P percent	K percent
No manure	11	---	---	---
Steer manure				
Fresh	32	53	24	74
Stacked	32	54	24	74
Anaerobic liquid	33	66	28	83
Aerobic liquid	20	13	14	34

*Application Rate: 15 Tons/Acre on Corn Grown on Miami Silt Loam in Pots.

In the absence of more specific data, these figures may serve as an indicator in estimating the percentages of nutrients which remain after treatment/storage and their value to the crop. For estimation of waste application rates, the dilution factor must be known. This should be available from prior system design or can be measured.

Information on soil fertility and hydraulic properties, plus plant nutrient, moisture, and salinity limitations can be obtained from the Cooperative Extension Service of the Land Grant universities and from the Soil Conservation Service. With a knowledge of crop nutrient requirements, soil analysis, and the above information, a rough estimate of the soil nutrient balance can be made and an appropriate application rate chosen.

For a slurry having a 2:1 water to fresh waste dilution factor (approximately 95 percent, wet basis), Berryman (12) recommends a maximum application rate of 925 to 1250 gallons/acre at 3 to 4 week intervals, with the heavier rates on light, coarse-textured soils; at higher dilutions, the rate may approach that for irrigation water. A commonly recommended figure for beef wastes in any form is 10 tons/acre/year, dry weight basis (35). However, uniformity of distribution is as important as average application rate.

Additional general observations on land disposal are:

1. Water pollution by runoff is a major hazard of liquid/slurry waste disposal; injection into the soil or immediate plowdown is recommended (10) for runoff control and minimization of anaerobic odor nuisance as well as better utilization of nutrients.
2. Disposal of slurry on pasture has minimized runoff pollution. However, there is danger of nitrate buildup in forage; at heavy application rates, pasture palatability to cattle is lessened (34).
3. Some form of manure storage during winter conditions is a necessity, since temperature-delayed biological activity coupled with frozen ground can lead to serious springtime water pollution.
4. Corn, in particular, has been shown to respond well to slurry application; legumes, on the other hand, have been rendered susceptible to weed intrusion and have been reduced in nitrogen-fixing ability by heavy application of slurries (12, 35).

REFERENCES

1. Anon., "How We Handle Liquid Manure," *Hoard's Dairyman*, pp. 1254-1255 (November 25, 1965).

2. Anon., "This Liquid Manure System Works," *Hoard's Dairyman*, pp. 16-18 (January 10, 1967).

3. Anon., *Beef Housing and Equipment Handbook*, Midwest Plan Service, Ames, Iowa (1965).

4. Anon., "Morales Feedlots Build Huge Slab to Eliminate Pollution Problems," *West Texas Livestock Weekly*, p. 11 (May 14, 1970).

5. Anon., *A Method of Manure Disposal for a Beef Packing Operation*, Water Pollution Control Research Series, U. S. Environmental Protection Agency (in press).

6. Anthony, W. B., "Cattle Manure: Re-use Through Wastage, Feeding," *Animal Waste Management*, Cornell University, Ithaca, New York, pp. 105-113 (1969).

7. Appell, H. R., Y. C. Fu, S. Friedman, P. M. Yavorsky, and I. Wender, "Converting Organic Wastes to Oil," *Agricultural Engineering*, Vol. 53, (3), pp. 17-19 (1972).

8. Aude, T. C., N. T. Cowder, T. L. Thompson, and E. J. Wasp, "Slurry Piping Systems: Trends, Design Methods, Guidelines," *Chemical Engineering*, pp. 74-90 (June 18, 1971).

9. Barth, C. L., and L. B. Polkowski, "Low-Volume Surface - Layer Aeration Conditioned Manure Storage," *Livestock Waste Management and Pollution Control*, ASAE, St. Joseph, Michigan, pp. 279-282 (1971).

10. Bartlett, H. D., and L. F. Marriott, "Subsurface Disposal of Liquid Manure," *Livestock Waste Management and Pollution Abatement*, ASAE, St. Joseph, Michigan, pp. 258-260 (1971).

11. Bates, D. W. "Handling Methods for Liquid Manure are Tested," *Hoard's Dairyman*, p. 273 (March 10, 1971).

12. Berryman, C. "The Problem of Disposal of Farm Wastes with Particular Reference to Maintaining Soil Fertility," *Farm Wastes*, University of Newcastle-upon-Tyne, Newcastle-upon-Tyne, England, pp. 19-28 (1970).

13. Butchbaker, A. F., J. E. Garton, G. W. A. Mahoney, and M. D. Paine, *Evaluation of Beef Cattle Feedlot Waste Management Alternatives*, Water Pollution Control Research Series 13040 FXG, U. S. Environmental Protection Agency (1971).

14. Butchbaker, A. F., *Feedlot Runoff Disposal on Grass and Crops*, Oklahoma State University Extension Publication No. 7521, Oklahoma State University, Stillwater, Oklahoma (1972).

15. Culpin, C., "Equipment for Disposal of Agricultural Effluents," *Chemistry and Industry*, pp. 350-353 (February 29, 1964).

16. Dale, A. C., J. R. Ogilvie, A. C. Chang, M. P. Douglas, and J. A. Lindley, "Disposal of Dairy Cattle Waste by Aerated Lagoons and Irrigation," *Animal Waste Management*, Cornell University, Ithaca, New York, pp. 150-159 (1969).

17. Edwards, J. B., and J. B. Robinson, "Changes in Composition of Continuously Aerated Poultry Manure with Special Reference to Nitrogen," *Animal Waste Management*, Cornell University, Ithaca, New York, pp. 178-184 (1969).

18. Erickson, A. E., J. M. Tiedje, B. G. Ellis, C. M. Hansen, "Initial Observations of Several Medium Sized Barriered Landscape Water Renovation Systems for Animal Wastes," *Waste Management Research*, Cornell University, Ithaca, New York, pp. 405-410 (1972).

19. Estep, A. J., "Handling Liquid Manure by Sprinkler," *Washington State University Agricultural Extension Newsletter*.

20. Fogg, C. E., "Lagoon Systems," Sanitary Engineering Training Course, Soil Conservation Service, Fort Worth, Texas (1972).

21. Glerum, J. C., G. Klomp, and H. R. Poelma, "The Separation of Solid and Liquid Parts of Pig Slurry," Livestock Waste Management and Pollution Control, ASAE, St. Joseph, Michigan, pp. 345-347 (1971).

22. Hart, S. A., J. A. Moore, and W. F. Hale, "Pumping Manure Slurries," Management of Farm Animal Wastes, ASAE, St. Joseph Michigan, pp. 34-37 (1966).

23. Hensler, R. F., W. H. Erhardt, and L. M. Walsh, "Effect of Manure Handling Systems on Plant Nutrients Cycling," Livestock Waste Management and Pollution Abatement, ASAE, St. Joseph, Michigan, pp. 254-257 (1971).

24. Holmes, L. W., D. L. Day, and J. T. Pfeffer, "Concentrations of Proteinaceous Solids from Oxidation Ditch Mixed Liquor," Livestock Waste Management and Pollution Control, ASAE, St. Joseph, Michigan, pp. 351-354 (1971).

25. Jedele, D. G., and F. W. Andrew, "Slotted-floor, Cold-confinement Beef-cattle Housing," ASAE Paper 72-448, ASAE, St. Joseph, Michigan (1972).

26. Jones, D. D., D. L. Day, and A. C. Dale, Aerobic Treatment of Livestock Wastes, Agricultural Experiment Station Bulletin 737, University of Illinois, in Cooperation with Purdue University, Urban-Champaign, Illinois, (1970).

27. Kumar, M., H. D. Bartlett, and N. N. Mohsemin, Flow Properties of Animal Wastes Slurries, ASAE Paper No. 70-911, ASAE, St. Joseph, Michigan (1970).

28. Loehr, R. C., and R. W. Agnew, "Cattle Wastes Pollution and Potential Treatment," Journal of the Sanitary Engineering Division ASCE, Vol. 93 (5A-4) pp. 55-72 (1967).

29. Loehr, R. C., Pollution Implications of Animal Wastes--A Forward Oriented Review, FWPCA, USDI, RSKWRC, P. O. Box 1198, Ada, Oklahoma (1968).

30. Loehr, R. C., "Liquid Waste Treatment II-Oxidation Ponds and Aerated Lagoons," Agricultural Wastes: Principles and Guidelines for Practical Solutions, Cornell University, Ithaca, New York, pp. 63-71 (1971).

31. Loehr, R. C., "Liquid Waste Treatment III-The Oxidation Ditch," Agricultural Wastes Principles and Guidelines for Practical Solutions, Cornell University, Ithaca, New York, pp. 72-78 (1971).

32. Ludington, D. C., "Solids Destruction or Severe Treatment," Agricultural Wastes: Principles and Guidelines for Practical, Solutions, Cornell University, Ithaca, New York, pp. 102-106 (1971).

33. Maddex, R. L., Materials Handling Systems and Farmstead Layouts, Department of Agricultural Engineering, Michigan State University, E. Lansing, Michigan (1966).

34. McCaskey, T. A., G. H. Rollins, and J. A. Little, "Water Quality of Runoff from Grassland Applied with Liquid, Semi-liquid and 'Dry' Dairy Waste," Livestock Waste Managment and Pollution Abatement, ASAE, St. Joseph, Michigan, pp. 239-242 (1971).

35. Miner, J. R., editor, Farm Animal-Waste Management, Special Report No. 67, North Central Regional Publication 206, Agricultural and Home Economics Experiment Station, Iowa State University, Ames, Iowa (1971).

36. Moore, J. A., R. E. Larson, and E. R. Allred, "Study of the Use of the Oxidation Ditch to Stabilize Beef Animal Manures in Cold Climate," Animal Waste Management, Cornell University, Ithaca, New York, pp. 172-177 (1969).

37. Ngoddy, P. O., J. P. Harper, R. K. Collins, G. D. Wells, and F. A. Heidar, *Closed System Waste Management for Livestock*, Water Pollution Control Research Series, No. 13040 DKP, U. S. Environmental Protection Agency (1971).

38. Nogaj, R. J., "Selecting Wastewater Aeration Equipment," *Chemical Engineering*, pp. 95-102 (April 17, 1972).

39. Nordstedt, R. A., L. B. Baldwin, and C. C. Hortenstine, "Multistage Lagoon Systems for Treatment of Dairy Farm Waste," *Livestock Waste Management and Pollution Abatement*, ASAE, St. Joseph, Michigan, pp. 78-80 (1971).

40. Payne, J. I., "Land Disposal and Storage of Farm Wastes," *Farm Wastes*, University of Newcastle-upon-Tyne, Newcastle-upon-Tyne, England, pp. 116-121 (1970).

41. Person, H. L., J. R. Miner, T. E. Hazen, and A. R. Mann, *A Comparison of Three Systems for Transport and Treatment of Swine Manure*, ASAE Paper No. 72-439, ASAE, St. Joseph, Michigan (1972).

42. Peterson, M., *The Missouri Irrigation and Land Forming Newsletter*, Cooperative Extension Service, University of Missouri, Columbia, Missouri, *Vol. 1*, No. 4 (August, 1971).

43. Pratt, G. L., R. E. Harkness, R. G. Butler, J. L. Parson, and M. L. Buchanon, "Treatment of Beef-cattle Waste Water for Possible Reuse," *Transactions of the ASAE*, Vol. 12, pp. 471-473 (1969).

44. Reed, C. H., "Specifications for Equipment for Liquid Manure Disposal by the Plow-Furrow-Cover Method," *Animal Waste Management*, Cornell University, Ithaca, New York, pp. 114-119 (1969).

45. Roberts, R. N., "Pipelines for Process Slurries," *Chemical Engineering*, pp. 125-130 (July 31, 1967).

46. Roper, W. L., "How to Build a Liquid Manure Tank," Hoard's Dairyman, p. 827 (July 10, 1967).

47. Sewell, J. I., Manure Slurry Irrigation System Receiving Lot Runoff, ASAE Paper No. 72-443, ASAE, St. Joseph, Michigan (1972).

48. Sobel, A. T., "Physical Properties of Animal Manures Associated with Handling," Management of Farm Animal Wastes, ASAE, St. Joseph, Michigan, pp. 27-31, (1966).

49. Staley, L. M., N. R. Bulley, and T. A. Windt, "Pumping Characteristics, Biological and Chemical Properties of Dairy Manure Slurries," Livestock Waste Management and Pollution Abatement, ASAE, St. Joseph, Michigan, pp. 142-145 (1971).

50. Taiganides, E. P., and R. K. White, "The Menace of Noxious Gases in Animal Units," Transactions of the ASAE, Vol. 12, No. 3, pp. 359-362 (1969).

51. Taylor, J. C., "Regulatory Aspects of Recycled Livestock and Poultry Wastes," Livestock Waste Management and Pollution Abatement, ASAE, St. Joseph, Michigan, pp. 291-292 (1971).

52. Turnbull, J. E., F. R. Hore, and M. Feldman, "A Land Recycling Liquid Manure System for a Large-scale Confinement Operation in a Cold Climate," Livestock Waste Management and Pollution Abatement, ASAE, St. Joseph, Michigan, pp. 39-43 (1971).

53. Turner, D. O., and D. E. Proctor, "A Farm Scale Dairy Waste Disposal System," Livestock Waste Management and Pollution Abatement, ASAE, St. Joseph, Michigan, pp. 85-88 (1971).

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ECONOMICS OF INTEGRATED WASTES CONTROL SYSTEMS

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SECTION VII

FIGURES

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SECTION VII

ECONOMICS OF INTEGRATED WASTES CONTROL SYSTEMS

The usefulness of published economic data depends primarily upon two factors: (a) the form in which it is given, and (b) the needs of the reader. Thus a rule of thumb such as "$15 per head total facility cost for open lots" is far too general to aid in choosing between alternate waste management systems. At the same time, even a quite detailed capital cost breakdown for a particular enterprise may be difficult to relate to potential costs of another operation because of differences in size, topography, climate, etc. In choosing a format for this section, three major uses for economic information by the feedlot designer-operator were anticipated:

1. preparing detailed cost estimates for modifications or replacement of components in an existing waste management system,
2. detailing a cost estimate of a total wastes management system prior to construction, and
3. comparing two or more potential wastes management systems in the early stages of design.

The "nuts and bolts" economic information needed for the first use is obviously not convenient for the third. In seeking a compromise, the following objectives were used as guidelines:

1. to provide unit prices of those construction materials which would commonly be used for fabrication of wastes management system components by the feedlot or its contractors;
2. to furnish capital costs for purchased wastes handling and storage system components, or to provide a means of extrapolating limited cost data on these items;
3. to supply operating cost information for owned machinery, as well as custom rates for contracted work; and

4. to enable a fairly rapid estimate of system costs by use of the economic information in this section in concert with the design procedures of the preceding sections.

Items not considered pertinent to choice of waste management system, such as feed mills and storages, have been omitted. To compensate for the lack of emphasis on economic comparison of total waste management systems (which depends greatly on the circumstances of the individual enterprise), the information given in the initial sections of the manual can provide optional choices of feasible wastes management systems based on climate, topography, and personal preference. Table VII-1, drawn from an extensive economic modeling study of alternatives, offers further qualitative guidance with respect to economics and pollution control. By using this procedure to eliminate undesirable options, manual economic evaluation of one or two remaining alternative systems based on the design sections then becomes a feasible, though somewhat tedious, operation.

For examination of additional results of wastes management systems studies, the interested reader is referred to the work of Butchbaker et al. (13), Owens and Griffin (24) and Nordstedt (23); the associated programs can indeed be useful for those users having access to an adequate computer.

In interpreting the published results of these studies, however, three cautions are in order. First, because of the rapid change in costs of material and labor and the differences in location of the studies, extrapolation of the results is risky. Second, it is unlikely that the situation modeled in these studies closely corresponds to that of a given feedlot; thus, a judgment of the applicability of the results must be made. Third, unless the economic assumptions of the study are clearly stated, it may be impossible to decompose the published data into meaningful information (e.g., do operating costs include labor? does investment cost include equipment installation charges?).

TABLE VII-1

RANKING OF SELECTED WASTE MANAGEMENT SYSTEMS ACCORDING TO POTENTIAL FOR POLLUTION CONTROL AND LEAST COST (13)

Rank	Pollution Control	Rank	Economic
1	Cable scraper, with shallow pit and lagoon or irrigation	1	Unpaved open feedlot with detention reservoirs or lagoons only, evaporation
2	Oxidation ditch, lagoon and irrigation or evaporation	2	Unpaved open feedlot with settling basins, detention reservoirs, irrigation
3	Deep storage pit under slotted floor, slurry hauling with soil injection system	3	Solid floor building, solid waste handling only, composting or field application
4	Solid floor building, solid waste handling only, composting or field application	4	Deep storage pit under slotted floor, slurry hauling with soil injection system
5	Paved open feedlot with flushing system and irrigation	5	Paved open feedlot with flushing system and irrigation
6	Unpaved open feedlot with settling basins, detention reservoir, irrigation	6	Cable scraper with shallow pit and lagoon or irrigation
7	Unpaved open feedlot with detention reservoirs or lagoons only, evaporation	7	Oxidation ditch, lagoon and irrigation or evaporation

In the subsequent sections of this section, the following order of presentation is used. First, cost engineering techniques and rules of thumb for extending limited economic data are given. Second, the economics of machinery are discussed, followed by tables of cost-capacity data for construction and wastes handling equipment. Next, a discussion of the economics of structures is followed by tables of economic information on wastes holding/treatment structures, housing facilities and accessories, and materials of construction. Finally, information regarding the economics of processes commonly considered for reuse or destruction of wastes is summarized.

To illustrate the potential use of these economic data and methods, an example is in order. Figure VII-1, taken from a recent issue of Feedlot Management (4), illustrates a paved lot design with several attractive features. Although this unit is designed for only 100 head, it can easily be used (with conversion to fenceline feeding) as a module to build a much larger operation. The paved lot allows increased animal density, can be easily scraped or flushed, and improves animal comfort.

In the example (which is the final portion of the section), a detailed estimate of current facility costs will be made by use of the techniques and data to be presented. Then, after the addition of design information from Section VI, three alternative liquid/slurry waste management systems will be compared on the basis of both investment and operating cost. To aid in following the example, the reader is urged to carefully follow the cost estimation techniques and to familiarize himself with the location of information given in the tables.

USE OF ECONOMIC DATA FOR COST ESTIMATION

Cost estimation, at its best, is an inexact art.

Because of the accelerating rise in costs of materials and labor, the difficulty in obtaining price information, and the constant changes in technology, it is axiomatic that published economic data are out of date.

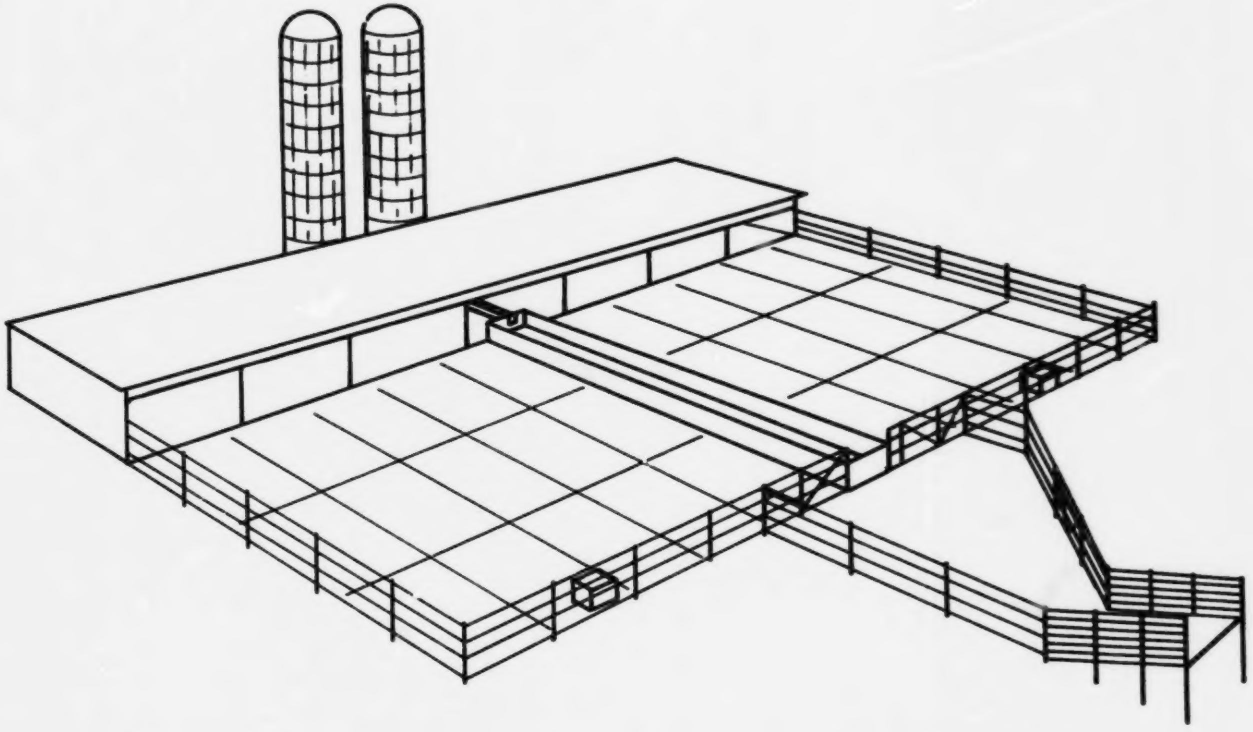

FIGURE VII-1. 100-HEAD PAVED LOT WITH COVERED REST AREA (4).

To extend the usefulness of the limited cost information given in this section, two aids, the cost index and cost-capacity factor, are available.

Cost Index

The cost index has been developed as a means of adjusting past published cost data to present levels. In construction of a cost index, a certain year is typically chosen as the base period. Next, a pertinent economic commodity or group of commodities is chosen as an indicator of the status of the industry as a whole and the price(s) of these during the base year is used to create the base index, using a convenient formula or weighting procedure. During later time periods, the same scheme is used to compute current cost indices, giving a comparative history of the performance of the industry as a whole. The ratio of the cost indices of any two time periods gives a multiplier for translating past costs to present levels.

For estimation of feedlot construction costs, the "Construction Index," based on a nationwide weighted average of prices of common construction materials and wage rates, was chosen as the most representative and readily available. The Engineering News-Record construction trade journal contains weekly updates of the index. Figure VII-2, which summarizes the recent history of the Construction Index, can be used to update all construction costs given in the tables of this section; it may also, with somewhat less accuracy, be used to extrapolate past published machinery prices to current levels. In a similar fashion, the "Materials Index" given in Figure VII-2 can be used to adjust the construction raw materials prices given in Table VII-2.

An example of the use of the cost index is taken from Table VII-3. A slurry storage tank of poured concrete construction was estimated to cost $25 per cubic yard of capacity in 1964, including labor. Using the cost index, the problem is to estimate the current (1972) cost. From Figure VII-2, the Construction Index averaged 925 in 1964, and is estimated to average 1725 during 1972. Hence:

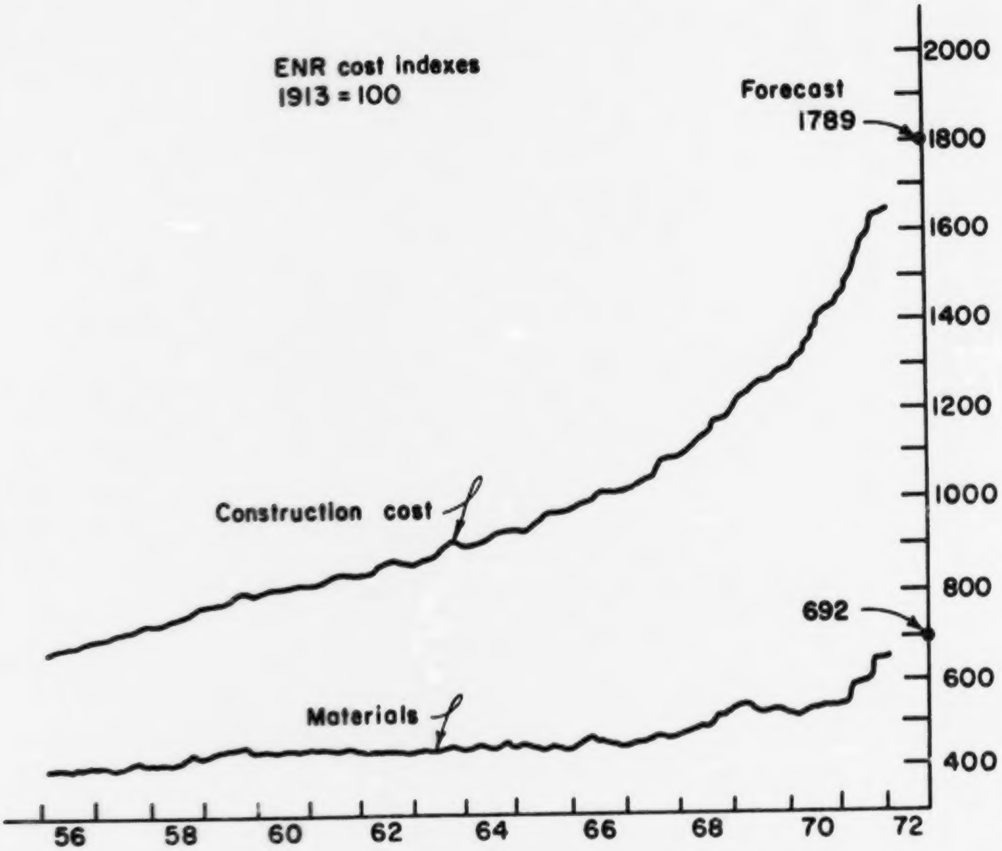

FIGURE VII-2. ENGINEERING NEWS-RECORD, COST INDICES (7).

TABLE VII-2

LIQUID/SLURRY WASTES HANDLING EQUIPMENT

Item	Reported Range of Capacities	Machine Size Or Capacity	Investment Cost Cost	Investment Cost Date	Investment Cost Location	Operating Cost	Machine Life	Comment	Source(s)
Vacuum Type Tank Wagon	750-1500 gal.	750 gal. 1100 gal. 1500 gal.	$ 1200 1500 1800-1900	'71 '71 '71	Ind. Ind. Ind.-Okla.	$4.00/hr. 4.00/hr. 4.00/hr.	6 years (2000 hr.)	Annual Depreciation, Interest, Repairs, Insurance, Taxes = 15% of Investment Cost.	(6,11,13,22)
Liquid Manure Spreader Pull Type	415.6-3000 gal. 14-35 ft. Swath	1400 gal.	1740	'71	Okla.		5 years (2000 hr.)	Annual Depreciation, Interest Repairs, Insurance Taxes = 15% of Investment Cost.	(6,11,13)
Liquid Combination Spreader-Injector, Pull Type	800-3000 gal. 29-40 ft. Swath 2 Injector Shanks, Penetration 6-14"	1400 gal.	2894	'71	Okla.		2000 hr.		(6,13)
Liquid Spreader Truck	280-380 ft.^{3}	55.7 yd.^{3}/hr. (based on 0.25 mile hauling distance)	9300	'71	Okla.	2.08/hr.	2000 hr.	Operating Cost Incl. Fuel & Lub.	(6,13)
Liquid Manure Pump		1400 gpm	1433	'71	Okla.		5 years (2000 hr.)	Annual Depreciation, Interest Repairs, Insurance, Taxes = 20% of Investment Cost	(11,13)
Centrifugal Pump			See Appendix Figs. VII-1 and VII-2	'64		0.22/Acre-inch Per 100 ft. of head	8 years		(21,25)
Electric Motor Drive			See Appendix Figs. VII-3 and VII-4				8 years		(21)

TABLE VII-2 (CONTINUED)

Item	Range of Capacities	Machine Size Or Capacity	Investment Cost			Operating Cost	Machine Life	Comment	Source(s)
			Cost	Date	Location				
Aluminum Irrigation Pipe		6-10" diam. 30' lengths	$0.85-1.25/ft.	'72	Kan.		10 years	For Gated Pipe. Add 10¢/ft.	(25)
Manure Gun Type Sprinkler + 1/8 mi. hose		400 gpm (125 psi at Pivot)	5000	'72	Kan.		10 years		(25)
Same with pump			7200	'72	Ore.				(8)
Center Pivot Irrigation System (no pump)		160 A. Nominal (132A) Coverage (75 psi at Pivot)	19000	'72	Kan.				(25)

TABLE VII-3

LIQUID/SLURRY STORAGE/TREATMENT STRUCTURES

Structure	Component	Description	Investment Cost (Date)	Operating Cost (Date)	Comment	Source(s)
Shallow Underfloor Pit		2 ft. Depth 4 ft. Depth	50¢/ft.^{2} ('71) 45-65¢/ft.^{3} ('71)			(13,22)
	Cable Powered Scraper		$2280 Inc. Motor ('71)		2500 Hr. Life	(13)
	Electric Motor		$80-130./Hp ('71) (Also See Fig. 7) (Table)		Valid for 1/4-5 HP Use Higher Price For Highest Quality Motor	(28)
Deep Underfloor Pit		8 ft. Depth	50-75¢/ft.^{3} ('71) $1.00/ft.^{2}			(22)
	Pump	1400 gpm	$1433 ('71)		Also See Appendix Fig. VII-1	(13)
	Agitator & Pump Combination	7 ft. Long 200 gpm @ 100 psi 30 HP electric Motor	$1895 Ore. ('72)		For Use in 8 ft. Deep Tank	(8)
		16 ft. Long Same Specs.	$2070 Ore. ('72)			(8)
Storage Tank		Concrete Silo Stave Construction	NY ('69) 22¢/ft.^{3}			(14)
		Glasslined Metal Construction	NY ('69) >$1.00/ft.^{3}			(14)
		Poured Concrete Construction	('69) $28/yd.^{3}		Based on: 1 yd.^{3} Concrete 17.5 ft..^{3} Forms @ $1.00/ft.^{3}, 115 lb. Reinforcing Steel @	(21)

TABLE VII-3 (CONTINUED)

Structure	Component	Description	Investment Cost (Date)	Operating Cost (Date)	Comment	Source(s)
Oxidation Ditch		4 ft. Depth Incl. Rotor	50-75¢/ft.^{3} ('71)			(22)
	Rotor	8 ft. Length. 5 HP Unit		\$1-\$2/day ('71) Ind.	Serves 100 head Weight ≤1000#	(22)
	Rotor		\$2226 ('71) Okla.		Serves 500 head 8000 Hr. Life	(13)
Aerobic Lagoon		Total Investment Cost	1-2¢/Gal. ('71) of Capacity			(13)
		Excavation Only	\$0.30/yd.^{3} ('71)	Clean out by Dragline (1/2 yd.^{3}) \$9-\$25/Hr. ('70)		(13,27)
	Aerator	75 HP: Oxygen Transfer Rate = 2.0#/HP-Hr.	\$13900 ('70)			(20)
		5 HP	\$2500 ('69)			(31)
	Centrifugal Pump				See Appendix Fig. VII-1	
Anaerobic Lagoon		Total Investment Cost	1-2¢/Gal. ('71) Of Capacity		For Individual Machine Work Rates and Cost See Tables VII-5 & VII-14	(13)
		Excavation Only	\$0.30/yd.^{3} ('71)	Clean out by Drag line (1/2 yd.^{3}) \$9-\$25/hr. ('70)		(13,27)
	Centrifugal Pump				See Appendix Fig. VII-1	

$$1972\ \text{Cost} = \frac{1972\ \text{Index}}{1964\ \text{Index}}\ (1964\ \text{Cost}) \ldots\ldots\ldots\ldots\ldots\ldots\ \text{EQN (VII-1)}$$

$$1972\ \text{Cost} = \frac{1725}{925} \times \$28 = \$52/\text{yd.}^3\ \text{capacity}$$

Cost-Capacity Factor

A second difficulty encountered in using published cost data is that of extending a single given cost value to machines (or enterprises) of the same generic type, but of a different capacity or size. For example, are capital costs for a 10,000-head feedlot approximately twice those for a 5,000-head lot of the same general design? Is a 60-HP tractor twice as expensive as a 30-HP tractor?

To assist the cost estimator with questions of this nature, the concept of a "cost-capacity factor" was developed. From analysis of many cost-capacity data for industries, products, and machines, it has been noted that the equation:

$$C_2 = C_1\ (Q_2/Q_1)^x \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ \text{EQN (VII-2)}$$

where: C_2 = desired cost of capacity Q_2
C_1 = known cost of capacity Q_1

can be used to describe the cost-capacity relationship of most sets of similar items. It is only necessary that capacities Q_1 and Q_2 be expressed in the same units. The exponent (cost-capacity factor) has been found to range from <0.2 to >1.0 for various products. However, in a surprising number of cases, its value is approximately 0.6; hence, in the absence of better information this fraction is often used (this is known as the "six-tenths factor rule"). Naturally, the closer the capacity of the item with the unkown cost to that of the item whose cost is known, the greater the expectation of accuracy.

In the tables which follow, often only a single cost data point is available for a given component. If the user requires cost information for a similar item of different capacity, this technique can be employed.

An example, taken from Table VII-2, illustrates the use of this method and provides a check on its applicability. In the table, a 750-gallon vacuum-type tank wagon is listed at $1200 (date: 1971). It is desired to find the cost of a 1500-gallon wagon of the same type. Substituting into EQN (VII-2) and using the "six-tenths factor rule":

$$\$1200\left(\frac{1500}{750}\right)^{0.6} = \$1820$$

In Table VII-2, the actual 1971 cost of such a wagon is given as $1800 to $1900. To complete the transformation of the data into a current cost, it would next be necessary to employ the cost index, as explained in the previous subsection.

Economics of Machinery

The economics of farm machinery has commonly been divided into categories of fixed cost (first cost, depreciation, taxes, shelter, insurance, and interest) and variable cost (fuel, lubrication, maintenance, and repairs). From these definitions, it is apparent that fixed costs are incurred regardless of the hours of machine operation, while variable costs depend upon the rate of use.

Investment cost (first cost) for common feedlot machinery and, in some cases, an estimation of machinery life are given in Tables VII-2, 4, and 5. For tax purposes, the standard machine lifetime is assumed to be ten years. The depreciation schedule is somewhat arbitrary and is not considered pertinent for cost evaluations. Estimates for the remaining components of fixed cost, on an annual basis, are:

1. Taxes: less than or equal to 2 percent of the remaining value of the machine;
2. Shelter: approximately $0.07 per square foot, or 1 to 2 percent of the remaining value of the machine;

TABLE VII-4

SOLIDS HANDLING EQUIPMENT (WASTES AND/OR CONSTRUCTION)

Item	Reported Range Of Capacities	Machine Size Or Capacity	Investment Cost			Operating Cost	Machine Life	Comment	Source(s)
			Cost	Date	Location				
Backhoe	1.3-13.5 ft.^{3} Bucket Cap. (Heaped)								(6)
Tractor Shovel	2-4 yd.^{3} Bucket	2 yd.^{3} 3 yd.^{3} 4 yd.^{3}	26300 28700 35600	'68 '68 '68		Labor $4.70-8.06 /Hr. ('70)			(3,21)
Grader		1210 yd.^{3}/hr.	22325	'71	Okla.	$2.[illegible]5/hr. Labor $3.89-7.[illegible]/hr. ('70)		Operating Cost Incl. Fuel & Lub.	(3,13)
Industrial Type Loader	8-108 ft.^{3}	Gasoline 2 yd.^{3} 4 yd.^{3} Diesel 2 yd.^{3} 4 yd.^{3}	 21000 33700 22900 36500	 '68 '68 '68 '68					(6,16)
Skid steer Loader	5-30 3/8 ft.^{3} Buckets (Heaped)	168 yd.^{3}/r.	31100	'71	Okla.	$1.87/hr.	12000 hr.	Operating Cost Incl. Fuel & Lub.	(6,13)
Dump Truck		39.6 yd.^{3}/hr. (0.25 mile hauling distance)	9700	'71	Okla.	$1.91/hr Labor $3.00-6.81/hr. ('70)	2000 hr.	Operating Cost Incl. Fuel & Lub	(3,13)
Elevating Scraper		105 yd.^{3}/hr.	37226	'71	Okla.	$2.14/hr.	12000 hr.	Operating Cost Incl. Fuel & Lub	(13)
Rotary Scraper		56 yd.^{3}/hr.	5895	'71	Okla.		5000 hr.		(13)

TABLE VII-4 (CONTINUED)

Item	Reported Range Of Capacities	Machine Size Or Capacity	Investment Cost Cost	 Date	 Location	Operating Cost	Machine Life	Comment	Source(s)
Manure Fork	Max Dimensions 28" x 40" x 72" Min. Dimensions 17 7/8 x 25" x 34 3/4		1100	'71	Mich.	$0.32/hr.	10 years (2000 hr.)	Hydraulic Unit Operating Cost Incl. Repairs, Lub. and Oil	(6,28)
Manure Stacker			1100	'69	Wis.			Annual Depreciation, Interest, Repairs, Insurance, Taxes = 15% of Investment Cost	(11)
Pull Type Manure Spreader	70-524 bu.	155 bu. 175 bu. 180 bu.	1150 1250 1434	'71 '71 '71	Mich. Mich. Okla.	$0.46/hr. $0.50/hr	10 years (2500 hr.)	Operating Cost Incl. Repairs & Lub	(6,13,28)
Truck-Mounted Manure Spreader	177-524 bu	67.5 yd.^{3}/hr. (based on 0.25 mile hauling distance)	12800	'71	Okla.	$2.06/hr	2000 hr	Operating Cost Incl. Fuel & Lub	(6,28)

TABLE VII-5

MULTIPURPOSE (SOLIDS OR LIQUID SLURRY HANDLING) MACHINERY

Item	Reported Range Of Capacities	Machine Size Or Capacity	Investment Cost			Operating Cost	Machine Life	Comment	Source(s)
			Cost	Date	Location				
Wheel Tractor	38-140 HP (2-7 Plow)	Gasoline							
		38 HP (2 Plow)	4200	'71	Mich.	$0.73/hr.	10 years (6500 hr.)	Operating Cost Incl. Repairs, Fuel, Oil & Lub	(28)
		53 HP (3 Plow)	5600	'71	Mich.	$1.04/hr.			
		70 HP (4 Plow)	7400	'71	Mich.	$1.38/hr.			
		Diesel							
		70 HP (4 Plow)	7900	'71	Mich.	$1.11/hr.			
		90 HP (5 Plow)	10000	'71	Mich.	$1.47/hr.			
		115 HP (6 Plow)	11100	'71	Mich.	$1.76/hr.			
		140 HP (7 Plow)	14100	'71	Mich.	$2.34/hr.			
MOUNTED ACCESSORIES:									
Scraper Blade		6 ft. width Capacity: 350 yd.^{3}/hr. on 65 HP Tractor	$245 + Tractor	'71	Okla.		7500 hr.		(13)
Loader	30.5-93.3 HP Heaped Bucket: 9-72 ft.^{3}	37.2 yd.^{3}/hr on 65 HP Tractor 2 Bottom Plow Tractor with Loader can Backfill Narrow Trench at 300-500 lin. ft./hr	1230 + Tractor	'71	Okla.	$0.66/hr		Operating Cost Incl. Fuel & Lub.	(6,13)

TABLE VII-8 (CONTINUED)

Item	Reported Range Of Capacities	Machine Size Or Capacity	Cost	Investment Cost Date	Investment Cost Location	Operating Cost	Machine Life	Comment	Source(s)
TRAILED ACCESSORIES:									
—Plow, Pull Type		3-16", Auto Reset; 0.61 Machine Hrs/A.	1600	'71	Mich.	$1.20/hr.	8 years (1200 hr.)	Operating Cost Incl. Repairs, Lube. Capacities are Rated at 85% Field Eff., 4 MPH	(28)
		4-16", Auto Reset; 0.46 Machine Hrs./A.	2000	'71	Mich.	$1.44/hr.			
		5-16", Auto Reset; 0.37 Machine Hrs./A.	2350	'71	Mich.	$1.76/hr.			
		6-16", Auto Reset; 0.31 Machine Hrs./A.	2850	'71	Mich.	$2.[illegible]/hr.			
		7-16", Auto Reset	3150	'71	Mich.	$2.[illegible]/hr.			
—Disk, Tandem	12'-20'	12' (0.81 Machine Hrs./A.)	1300	'71	Mich.	$0.[illegible]/hr.	10 years (1500 hr.)	Operating Cost Inc. Repairs & Lube. Capacities are Rated at 85% Field Eff., 4 MPH	(28)
		16' (0.14 Machine Hrs./A.)	1600	'71	Mich.	$0.[illegible]/hr.			
		20'	2100	'71	Mich.	$0.86/hr.			
Dragline		156 yd.³/hr. for 1/2 yd.³ bucket	67500	'71	Okla.				(13)

3. Insurance: approximately 0.25 to 0.50 percent of the remaining value of the machine; and
4. Interest: approximately 7 to 9 percent of the remaining value of the machine.

Development of guidelines for estimation of operating cost is a much more difficult subject, since machine efficiency and operator skill and care vary widely. In the subsequent tables, operating cost rates are listed if known. Alternatively, Bowers (12) has developed a simplified method of estimating average fuel consumption rates, based on the first cost (list price) of the machine, machine type, and fuel used. To use this procedure, a "fuel consumption factor," read from Table VII-6, is substituted into the expression:

$$\text{Cost, \$/hr.} = \frac{(\text{Fuel Use Factor})(\text{Mach. List Price})(\text{Fuel Price/Gal.})}{\$1000} \quad \ldots\ldots \text{EQN (VII-3)}$$

Current per gallon prices for these fuels are typically $0.28 (less 6 cents farm refund) for gasoline, $0.19 for diesel, and $0.14-0.17 for LP gas. Total costs of oil, grease, and oil filter are estimated to be 15 percent of fuel cost.

For machines not found in the table, the following guidelines are offered:

1. Self-propelled machines average one gallon of fuel per acre in the field.
2. Machines with trailed implements average 3/4 gallon of fuel per acre.
3. Gasoline consumption can be estimated at 8.5 HP-hr./gallon (average power requirement for farm tractors is 55 percent of the maximum rated HP).

Again, costs of oil, grease, and oil filter total approximately 15 percent of fuel cost. Repair cost rates for several common farm machines are extensively discussed by Bowers (12).

TABLE VII-6

FUEL CONSUMPTION FACTORS (12)

Machine	Gasoline	Diesel	LP Gas
2-Wheel-Drive Tractor	0.69	0.44	0.78
4-Wheel-Drive Tractor	0.46	0.31	0.55
Crawler Tractor	0.36	0.25	0.44
Truck	1.00	0.64	1.10
Feed Truck with Power Box	0.36	0.25	0.44

Custom rates for common construction and feedlot maintenance operations are given in Table VII-14.

For electric motors, the operating cost depends upon the price of electricity, commonly 1 to 2 cents per KWH (1 KWH = 1.341 HP-hr.), and on the efficiency of the motor (normally 65 to 85 percent, with additional losses in the drive train).

Economics of Structures

Cost components of structures may be divided into the initial (capital) costs of materials, labor, and engineering, and annual costs of depreciation, interest, upkeep, taxes, and insurance. The annual costs are relatively constant and can be calculated as percentages of the capital costs.

To aid the user in determining capital costs, the overall "structures" classification has been divided into categories of waste storage and housing in Tables VII-3, 7, 8, 9, 10, and 11, respectively. For rapid estimates of investment cost, the information in these tables should normally be adequate; for more detailed estimates, based on construction plans, use of Table VII-12, "Raw Materials for Construction," is suggested. Cost updating can be done by using the Cost Index and

TABLE VII 7

SOLIDS SEPARATION STRUCTURES

Structure	Component	Description	Investment Cost (Date)	Operating Cost (Date)	Comment	Source(s)
Settling Basin		Total Investment Cost	1-2¢/Gal. of Capacity ('71)			(13)
		Excavation Only	$0.30/yd.^{3} ('71)			
	Tractor with Loader			$0.32/hr.	Not Incl. Labor	(28)
	Dragline	1/2 yd.^{3} Bucket		$9-$25/hr.	Incl. Labor	(27)
Porous Dam	Planking		$0.1175/Board ft. (Okla. '71)			(13)
	Crushed Stone		$3.50/yd.^{3} ('64)			(21)
	Tractor with Loader	Clean out		$0.32/hr.	Not incl Labor	(28)

TABLE VII-8

SOLIDS SYSTEMS

Structure	Component	Description	Investment Cost (Date)	Operating Cost (Date)	Comment	Source(s)
Manure Platform	Paving		$0.45/ft.^{2}			(13)
	Manure Stacker		$1,000 (Wis. '69)	Annual Depreciation Interest, Repairs, Insurance, Taxes = 15% of Investment Cost		(11)
	Tractor with Loader			$0.32/hr. Not Incl. Labor ('71)		(28)

TABLE VII- 9

CONFINEMENT BUILDING COMPONENTS

Item	Component	Description	Investment Cost (Location, Date)	Comment	Source(s)
Beef Barn		Open Front with Outdoor Lot, 4" Concrete Floor Galvanized Steel Siding	\$1.20-1.40 per ft.^{2} (Mich. '71)		(28)
		Same with Aluminum Siding	\$1.30-1.50 per ft.^{2} (Mich. '71)		(28)
Foundation		Incl. Excavation Backfill, and Forming: Flat Slab, 1 yd.^{3} Concrete, 5.3 ft.^{2} Forms 100# Reinforcing Steel	\$25/yd.^{3} ('68) Labor, Forms @ \$1.00/ft.	Based on 6 Man/hr. Labor, Forms @ \$1.00/ft.^{2}, Reinforcing Steel @ 15¢ per lb. (Also see Pit Costs in Table VII-8)	(16)
Pole Footings		Digging Hole	\$1.00/hole		(13,27)
		Concrete Footing	\$1.50/footing (Okla. '71)		(13)
loor		4" Reinforced Concrete	\$2.00/ft.^{2} ('64)	Incl. Labor	(21)
		Poured Concrete	\$0.45/ft.^{2} (Okla. '71)	Less Labor	(13)
		Slatted Floor- 8' Slats	\$1.00/ft.^{2} (Okla. '71)	Less Labor	(23)
Side Walls		Structure with Aluminum Siding	\$0.65/ft.^{2} ('64)	Incl. Labor	(21)
		Structure with Galvanized Steel Siding	\$0.55/ft.^{2} ('64)	Incl. Labor	(21)
		6" Block wall	\$1.10/ft.^{2}	Incl. Labor	(21)

TABLE VII-9 (CONTINUED)

Item	Component	Description	Investment Cost (Location, Date)	Comment	Source(s)
Side Walls	Structural Members	6" Diam Treated Pole	Cost, in \$/Pole Given by $30. - 5.853*L + 0.43863*L^2 - 0.01268*L^3 + 0.0001346*L^4$ Where L = Length, ft. (Okla., '71)		(13)
		8" Diam Treated Pole	\$0.69/Lin. Ft. (Okla, '71)		(13)
		Steel Column	\$1.72/ Lin. Ft. (Okla, '71)		(13)
	Siding	Galvanized Steel	\$0.11/ft.^{2} (Okla. '71)		(13)
		Wood	\$0.15/ft.^{2} (Okla., '71)		(13)
		Screen	\$0.09/ft.^{2} (Okla, '71)		(13)
	Insulation	Fiberglass	\$0.0175/ft.^{2}/inch Thickness (Okla., '71)		(13)
		Plastic Foam	\$0.08/ft.^{2}/inch Thickness (Okla,'71)		(13)
	Windows	Steel	\$4.50/ft.^{2} ('64)	Incl. Labor	(21)
		Aluminum	\$6.00/ft.^{2} ('64)	Incl. Labor	(21)
		Wood	\$1.80/ft.^{2} ('64)	Incl. Labor	(21)
	Doors	Steel Frame, 8' x 8' Metal Automatic	('64) \$850 Ea.	30 Man-Hrs. To Install	(21)
		12' x 12' Steel, Manual, Rolling	('64) \$600 Ea.	24 Man-Hrs. To Install	(21)

TABLE VII-9 (CONTINUED)

Item	Component	Description	Investment Cost	Comment	Source(s)
		4' x 8' Metal Single Slide	('64) $100 Ea.	5 Man-Hrs. To Install	(21)
		12' x 10' Wood Sectional Overhead	('64) $200 Ea.	6 Man-Hrs. To Install	(21)
		3' x 7' Wood Swing Exterior	('64) $60 Ea.	4 Man-Hrs. To Install	(21)
Truss	(Truss Costs are all calculated from the Equation: Investment Cost ($) = (A + B * Span + C* Span ** 2 + D * Span ** 3) * E Where Values of A, ..., E vary with construction style and materials; these are enumerated below. Span is to be given in feet.				
		Inverted Shed Style Building	(Okla. '71) A = -5.5 B = $0.2708\overline{3}$ C = $0.01041\overline{6}$ D = 0.0 E = 1.0		(13)
		Gable Type Building	(Okla. '71) A = -293. B = $23.331\overline{6}$ C = -0.5885 D = 0.00503 E = 1.0		(13)
		Open Web Steel Type Building	(Okla. '71) A = -18. B = 1.175 C = -0.0115 D = 0.0 E = 0.15* Span		(13)
Roofing			$0.11/ft. (Okla. '71)		(13)
Roof		Aluminum	$0.62/ft.^{2} ('64)	Including Labor	(21)
		Coated Steel	$0.52/ft.^{2} ('64)	Including Labor	(21)
Lighting			$0.15 Per 20 ft.^{2} of Floor Area ('71)		(13)

TABLE VII-9 (CONTINUED)

Item	Component	Description	Investment Cost (Date)	Comment	Source(s)
Service Entrance		For lighting and general purpose circuits, no large motors.	$30.34 ea. ('71)	Serves 500 Head Unit	(13)
Fan		17000 cfm	$339 ea. ('71)		(13)
Fence		Wire	$1.04/Lin. Ft. (Okla., '71)	Including Labor	(13)
		Cable	$1.95/Lin. Ft. (Okla, '71)	Including Labor	(13)
		Pipe	$1.65/Lin. Ft. (Okla.,'71)	Including Labor	(13)
		Wood	$1.25/Lin. Ft. (Okla. '71)	Including Labor	(13)

TABLE VII- 10

OPEN LOT COMPONENTS

Item	Component	Description	Investment Cost (Date)	Comment	Source(s)
Drainage System		Open Unpaved Lot	\$0.50/Head of Lot Capacity (Okla., '71)		(13)
		Open Paved Lot	\$1.00/Head of Lot Capacity (Okla.,'71)		(13)
Paving	Road	4" Concrete, Mesh Reinforced, 6" Base	\$6.50/yd.^{2} ('64)		(21)
		6" Thickness, 6" Base	\$7.50/yd.^{2} ('64)		(21)
		8" Thickness, 6" Base	\$8.50/yd.^{2} ('64)		(21)
		3" Asphalt, 12" Base	\$6.00/yd.^{2} ('64)		(21)
		Paving	\$0.45/ft.^{2}		(13)
		Gravel	\$0.10/ft.		(13)
	Lot	Paving	\$0.45/ft.^{2} (Okla., '71)		(13)
Windbreak			\$3.13/Lin. Ft. (Okla.,'71)	Including Labor	(13)
Fence		Wire	\$1.04/Lin. Ft. (Okla. '71)	Including Labor	(13)
		Cable	\$1.95/Lin. Ft. (Okla., '71)		(13)
Fence		Pipe	\$1.65/ Lin Ft.	Including Labor	(13)
		Wood	\$1.25/Lin. Ft.	Including Labor	(13)

TABLE VII-11

FEEDING EQUIPMENT

Item	Component	Description	(Date) Investment Cost	(Date) Operating Cost	Comment	Source(s)
Waterer		Indoor	$115 Per 200 Head + $0.60 Per Foot of Barn Length		Includes Plumbing	(13)
		Outdoor	$300 (Okla., '71)		Includes Heater, Plumbing and Slab	(13)
			$175-250 (Mich., '71)		Serves 75 Head Includes Heater	(28)
Feedbunk	Bunk	Wood	$2.00/Lin Ft. (Okla.,'71)			(13)
		Precast Concrete	$4.50/Lin. Ft. (Okla., '71)			(13)
		Slipform Concrete	$6.25/Lin Ft. (Okla., '71)		Including Labor	(13)
		Mechanical	$7.50/Lin Ft. (Okla., '71)			(13)
	Splashboards		$0.1175/Bd. Ft.			(13)
	Apron		$0.45/ft.^{2} (Okla.,'71)			(13)
	Conveyor	Auger	$1.20/ft. of Length/ inch of diameter ('71)		Includes Flighting, Tube, Powerhead, but not Motor	(28)
Feedbunk	Conveyor	9" Diam. Auger	$9.00-$11.00/ft..		No Motor	(28)
		Drive Unit and 5 HP Motor	$400-$700 Ea. (Mich., '71)		Max 100-125 Ft. Length	(28)
		Vibrating Conveyor (1964)	(See Figure VII-10)			
	Motor and Drive		(See Figures VII-8 and VII-9)			
	Trucking Cost			$1.91/Hr.	Includes Fuel and Lubrication	(13)

TABLE VII- 12

RAW MATERIALS FOR CONSTRUCTION

Item	Description	Unit Price (Date)	Installation Labor Requirement	Source(s)
Lumber	Structural, Plain	\$170./Thousand Board Ft. ('64)		(21)
	2 x 4 Fir	\$170.175/1000 Board Ft. ('72)		(7)
	2 x 4 Pine	\$161.112/ 1000 Board Ft. ('72)		(7)
	Structural, Creosoted	\$235./1000 Board Ft. ('64)		(21)
	3/8" Plywood	\$0.12/ft.^{2} ('64)		(21)
	1/2" Plywood	\$0.16/ft.^{2} ('64)		(21)
	5/8" Plywood	\$0.17/ft.^{2} ('64) \$164.35/1000 ft.^{2} ('72)		(21) (7)
	3/4" Plyform Plywood	\$254.839/1000ft.^{2} ('72)		(7)
	Treated 6" and 8" Poles	(See Table VII-11)		
Structural Steel	1 1/4" Grating	\$2.00/ft.^{2} ('64)	0.33 Man-Hr./Ft.^{2}	(21)
	Expanded Metal	\$1.50/ft.^{2}('64)	0.17 Man-Hr./Ft.^{2}	(21)
	5/16" Checker Plate	\$1.80/ft.^{2}('64)	0.13 Man-Hr./Ft.^{2}	(21)
	Ladder	\$2.50/Lin. Ft. ('64)	0.35 Man-Hr./Ft.^{2}	(21)
	Stairway	\$50./Vert. Ft. ('64)		
	Buidling Steel Shop Fabrication	\$0.20/Lb. ('64)	0.01 Man-Hr./Ft.	(21)
	Steel Platform and Support, Shop Fabricated	\$0.25/Lb. ('64)	0.02 Man-Hr./Lb.	(21)
	Steel Columns	\$1.72/Lin. Ft. ('71)		(13)
Aluminum Sheet Metal	0.063", Flat	\$0.39-0.54/Lb. ('70)		(2)
	0.032", corrugated Roofing	\$17.02-45.01/Square ('70)		(2)

TABLE VII- 12 (CONTINUED)

Item	Description	Unit Price (Date)	Installation Labor Requirement	Source(s)
Insulation	Fiberglass	\$0.0175/Ft.^{2}/inch thickness ('71)		(13)
	Plastic Foam	\$0.08/Ft.^{2}/inch thickness ('71)		(13)
Reinforced Concrete Pipe	18" Diam.	\$5.65-5.95/Lin. Ft. ('68)		(16)
	36" Diam.	\$14.75-17.23/Lin. Ft. ('68)		(16)
Vitrified Clay Sewer Pipe	8" Diam.	\$0.62-1.83/Ft. ('70)		(1)
	12"	\$1.17-3.03/ft		(1)
	18"	\$7.55-8.45/Lin. Ft. ('68)		(16)
	24"	\$6.00-11.43/Ft. ('70)		(1)
	36"	\$10.60-32.08/Ft. ('70)		(1)
Clay Drain Tile	6"	\$0.18-0.40/Ft. ('70)		(1)
	8"	\$0.25-0.82/Ft. ('70)		(1)
Sand		\$3.05-5.55/yd.^{3} ('68) \$3.186/Ton ('72)		(16) (7)
Gravel		\$1.30-3.00/yd.^{3}('68)		(16)
Fill Dirt		\$1.30-3.00/yd.^{3}('68)		(16)
Crush Stone	1 1/2" Diam.	\$2.55-5.19/yd. ('68) \$3.271/Ton ('72)		(16) (7)
Cement	Bulk	\$4.618/bbl. ('72)		(7)
Ready Mix concrete		\$18.573/yd.^{3}('72)		(7)
Concrete Blocks	8" x 8" x 16"	\$0.31 Ea. ('72)		(7)

capacity adjustment by means of the Cost-Capacity Factor. For some structural costs given in the tables, labor is not included; these values may be adjusted by adding 30 percent of the materials' cost. Engineering costs (with no pre-existing plans) are normally estimated at 10 percent of the overall project cost.

Table VII-13 allows the user to compute the combined annual costs of interest and depreciation, based on equal annual payments and using common interest rates and amortization periods for farm structures. For the remaining annual costs, upkeep of farm structures ranges from 1 to 4 percent of the original cost; insurance averages 0.15 percent of the original cost.

Operating costs for powered structure accessories (e.g., oxidation rotor) can be calculated from the information given in the preface to the subsection entitled "Economics of Machinery." Costs of construction operations and contracted waste removal from structures are given in Table VII-14, "Custom Rates."

Economics of Disposal, Destruction, and Reuse of Wastes

In this section, pertinent information for several potential processing or disposal operations is compiled (Tables VII-15-18). Because of the many variables associated with the individual feedlot, it is difficult to predict the economic feasibility of these operations for a given enterprise. However, from these tables, the user may be able to compare the information with his own operation.

Because of the extensive interest in the operations of drying and incineration, the following values for energy and cost are included:

Energy Source	Heating Value	Price	Thermal Efficiency	
			Drying	Heating
Natural Gas (Methane)	1,021,000 BTU/1000ft.^{3}	40¢/1000ft.^{3}	36-60%	50-85%
#2 Fuel Oil	138,500 BTU/Gal.	19¢/Gal.	36-60%	50-85%
Electricity	3413 BTU/KWH	1-2¢/KWH	36-60%	100%

TABLE VII-13

ANNUAL PAYMENT TO AMORTIZE A LOAN OF $1,000 - EVEN PAYMENT PLAN

Period in Years	5%	5 1/2%	6%	6 1/2%	7%	8%	9%
				(Annual payment in dollars)			
2	$537.80	$541.62	$545.44	549.26	$553.09	$560.77	$568.48
3	367.21	370.75	374.11	377.58	381.05	388.03	395.07
4	282.01	285.29	288.59	291.90	295.23	301.92	308.70
5	230.97	234.18	237.40	240.63	243.89	250.46	257.13
6	197.02	200.18	203.36	206.57	209.80	216.32	222.97
7	172.82	175.96	179.14	182.33	185.55	192.07	198.74
10	129.50	132.67	135.87	139.10	142.38	149.03	155.89
12	112.83	116.03	119.28	122.57	125.90	132.70	139.73
15	96.34	99.63	102.96	106.35	109.79	116.83	124.15
20	80.24	93.68	87.18	90.76	94.39	101.85	109.66
25	70.95	74.55	78.23	81.98	85.81	93.68	101.93
30	65.05	68.81	72.65	76.58	80.59	88.83	97.46
35	61.07	64.97	68.97	73.06	77.23	85.80	94.75
40	58.28	62.32	66.46	70.69	75.01	83.86	93.06
Never (interest only)	50.00	55.00	60.00	65.00	70.00	80.00	90.00

Example: The annual payments on a 10-year loan for $5,400 at 6% would be 5.4 x $135.87 = $733.70. (Note: Use 5.4 because this is the number of $1,000 units being borrowed.)

TABLE VII-14

CUSTOM RATES

Operation	Specifications	Charge	Location & Date	Comment	Source
SITE PREPARATION					
--Machine Cuts		\$0.50-0.63/yd.^{3}	68		
--Clearing and Grubbing		\$0.13-0.18/yd.^{2}	'68	Including	(16)
--General Grading		\$0.33-0.48/yd.^{2}	'68	Labor	
--Final Leveling		\$0.25-0.38/yd.^{2}	'68		
EXCAVATION					
--General		\$0.30/yd.^{3}	'71 (Okla.)	Including	
	Backhoe	\$6-25/hr.	'70 (Mich.)		(13,27)
	Dragline (1/2 yd.^{3})	\$9-25/hr.	'70 (Mich.)	Labor	
--Boring Postholes		\$0.10-1.00/hole	'70 (Mich.)		
--Foundation					
	Machine	\$1.50-1.75/yd.^{3}	'68	Including	(16)
	Machine Plus Hand Trim	\$2.50-3.75/yd.^{3}	'68	Labor	
	Hand Labor	\$7.75-12.50/yd.^{3}	'68		
--Machine Trenching	3 1/2 ft. Deep x 2 ft. Wide	\$0.38-0.50/lin. ft.	'68		
	4 ft. x 3 ft.	\$0.56-0.68/lin. ft.	'68	Including	(16)
	4 1/2 ft. x 4 ft.	\$1.12-1.25/lin. ft.	'68	Labor	
	5 ft. x 5 ft.	\$1.38-1.63/lin. ft.	'68		
--Hand Trenching		\$8.75-\$13.75/yd.^{3}	'68		(16)
Backfill (Trench & Foundation)	--Machine Plus Handtrim	\$1.44-\$1.68/yd.^{3}	'68	Including Labor	(16)
	Hand Labor	\$5.70-\$6.75/yd.^{3}	'68		(16)
Tiling	Machine	\$1.00-\$3.00/rod	'70 (Mich.)	Including Labor but not Tile	(27)

TABLE VII-14 (CONTINUED)

Operation	Specifications	Charge		Location & Date	Comment	Source
Manure Loading						
	--Using Tractor with Fork	$5.00-$10.00/hr.		'70 (Mich.)	Including Labor	(27)
Manure Field Spreading		$3.00-$7.00/hr.		'70 (Mich.)	Including Labor	(27)
Plowing		Per Acre	Per Hour	'70 (Mich.)		
	--3 Bottom	$3.50-$7.00	$4.00-$6.00			
	--4 Bottom	$3.50-$7.00	$4.00-$10.00	'70 (Mich.)	Including	(27)
	--5 Bottom	$3.50-$8.00	$6.00-$15.00			
	--6 Bottom	$3.50-$8.00	$6.00-$15.00		Labor	
	--7 Bottom	$3.50-$7.00	---			
	--8 Bottom	$5.00-$7.00	---			
Disking						
	8' Sections	$1.50-$4.00	$4.50-$7.50	'70 (Mich.)	Including	(27)
	10' Sections	$1.50-$4.00	$6.00-$12.00		Labor	
Bulldozing						
	8 ft. Blade	$7.00-$22.00/hr.		'70 (Mich.)	Including	(27)
	10 ft. Blade	$10.00-$25.00/hr.		'70 (Mich.)	Labor	
	12 ft. Blade	$15.00-$30.00/hr.		'70 (Mich.)		
Trucking						
	General	$3.00-$15.00/hr.		'70 (Mich.)	Including	(27)
		$0.20-$0.60/mile		'70 (Mich.)	Labor	(27)
	Manure Hauling	Free (Manure Worth $2.50/Ton Delivered Within 5 Mile Radius of Feedlot)		'71 (Southern High Plains)		(13)
Lot Cleaning						
	--Mechanical	$0.25/yd.^{3}		'68 (Calif.)	Sometimes Custom Operator Pays Lot Up To $0.25/Ton For Manure	(1[illegible],29)
	--Mechanical With Hand Labor	$0.392/yd.^{3}		'68 (Calif.)		(29)

TABLE VII-15

COMPOSTING

Plant Size (Location)	Process	Investment Cost (Date)	Operating Cost	Marketing Procedure	Product Selling Price	Source
100 Ton/Day	Moisture Content Reduced from 30% to 5% Wet Basis After Composting	$650,000 + Land Cost	$167,410 Annual Cost		$15.00/Ton (Estimated)	(13)
Serves 14,000 Head Feedlot (Calif.)	6 Months Composting No Screening	7¢/yd.^{3} ('68)	3.5¢/yd.^{3}	Sold in Pile. Buyer Furnishes Loading and Trucking Equipment	$1.00/yd.^{3}	((30)
	6 Months Composting Pulverized and Screened	15.5¢/yd.^{3}	49.5¢/yd.^{3}	Sold in Bulk. Free Free Delivery of >10 yd.^{3} within 15 mile radius	$2.40/yd.^{3}	(30)
	6 Months Composting Pulverized and Screened	17.5¢/yd.^{3}	1.70/yd.^{3}	Packaged in 2 ft.^{3}/bags	$3.80/yd.^{3}	(30)

TABLE VII-16

REFEEDING TO CATTLE

Form	Process	Process Cost	Product Value	Comment	Source(s)
"Floor Manure"	None		$12-$24/Ton		(22)
"Floor Manure"	Cooking		"Possibly $12-$24/Ton"		(22)
"Wastelage" (57% Manure, 43% Chopped Hay)	Mixing and Ensiling	$10/Ton	$25/Ton	"Value Comparable To That of Hay"	(22)
Oven Dry Basis	Drying (82.4 to 12.0% Moisture, Wet Basis.)	$63.65/Ton of Dry Material (40 Hr. Dryer Use Per Week) or $48.07/Ton (80 Hr. Dryer Use Per Week)	16.5% Protein		(26)

TABLE VII-17

FERTILIZER

Moisture Content	Nitrogen Content	Nitrogen Price	Phosphorous Content	Phosphorous Price	Potassium Content	Potassium Price	Total Value	Sour Source
"Liquid"		$0.045/LB_N$		$0.08/LB_P$		$0.036/LB_K$	$0.29- $0.69/ Ton	(22)
"Slurry"	6.4 LB_N/Ton (10-30% Recovery by Crop)	$0.11 /LB_N$	4.6$LB_{P_2 0_5}$/Ton (10-20% Recovery by Crop)	$0.09/LB_{P_2 0_5}$	7.2 $LB_{K_2 0}$/Ton (30-100% Recovery by Crop)	$0.045/LB_{K_2 0}$	$1.43/ Ton	(13)
80%. Wet	14LB_N/Ton	$0.10/LB_N$	9 $LB_{P_2 0_5}$/Ton	$0.10/LB_{P_2 0_5}$	11 $LB_{K_2 0}$/Ton	$0.05/LB_{K_2 0}$	$2.85/ Ton	(28)
"Oven Dry"	2.6% as N		1.2% as P		0.8% as K			(26)

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TABLE VII-18

DRYING AND INCINERATION

[illegible]	Volume Processed and Initial-Final Moisture Contents	Machine Specifications	Process Specifications	Investment Cost (Date)	Operating Cost	Comment	Sources
Drying	[illegible] Lb. Dried Material/Hour; 82.4-12.3% Wet Basis				2.6 Gal. Fuel Per Hour, 4.2 KWH/Hr. $63.65/Ton of Dried Manure for 40 Hr./Week Operation $48.07/Ton for 80 Hr./Week Operation (Labor Included).	This Size Machine Will Serve 22 1000 Lb. Animals on a 40 Hr./Week Operating Schedule	(17)
Drying (Rotary Drum)	Four Cattle Markets Averaging [illegible] Tons/Dry Mixed Manure-Bedding Initial MC Range 38.7-64.5%, Wet Basis	Ranges: 30-40 ft. Drum, 4-10 Ft. Diam. 10-50 HP Drive Dryer Fans 20-50 HP.	Material Shredded Before Drying Dryer Exhaust Temp = 300 °F		All Units: Cents Per Lb. of Dry Product Fuel: 0.085-0.2 Electricity: 0.075-0.2 Repairs: 0.3-0.4 Labor: 1.1-1.3 Misc: 0.05-0.09 Total: 1.6-2.2	Serves Average of 3700 Head Per Day Problems With Corrosion, Dust, Odor. Product Sold in 5-50 Lb. Bags With N-P-K Analyses of 0.5-0.5-0.5 to 2-1-2	(19)
Drying (Rotary Drum)	5500 Lb./Hr. 75-10%, Wet Basis	7.8' Wide x 10.0' High x 53 ft. Long 40 HP Fan 5 HP Drum Drive 7 1/2 HP Furnace Compressor		Dryer Cost: $30-35,000. With Installation and Accessories: $40-50,000 ('72)	6000 Ft.^{3}/Hr. of Nautral Gas @ 40¢/1000 Ft.^{3} = $2.40/Dry Ton Plus Electricity, Labor, Etc.	Information From Manufacturer's Literature	(5)
Incineration				$3000-$4000 Per Ton of 24-Hour Capacity ('68)	$5.00 Per Wet Ton (Estimated) Heat Value of Beef Manure = 6300 Btu/Lb. of Dry matter Latent Heat of Evaporation @ 212 °F 970 Btu/Lb. of Water	Max. Moisture Contnet For Combustion is Approximately 30%, Wet Basis	(18)

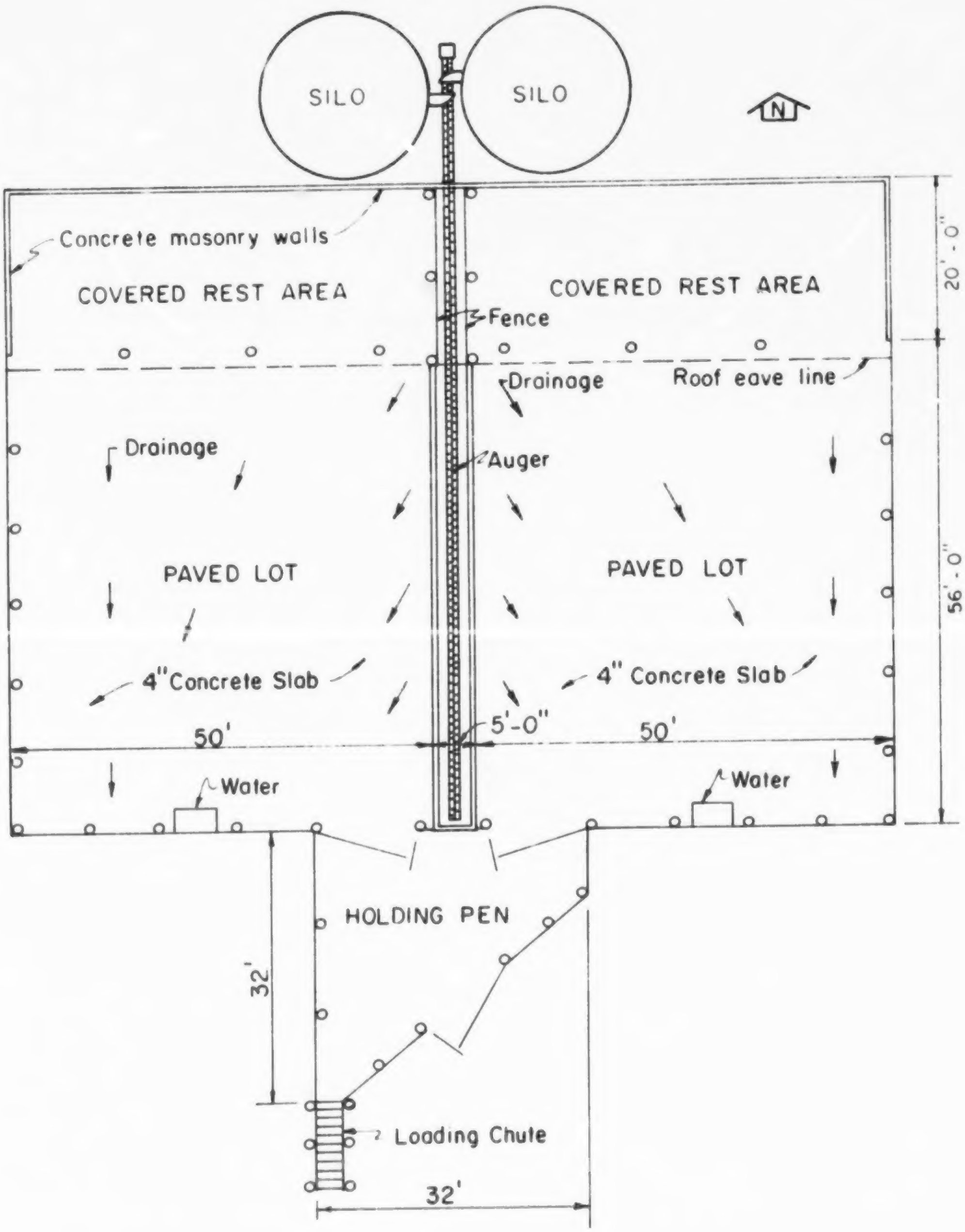

SILO
SILO
N
Concrete masonry walls
COVERED REST AREA
COVERED REST AREA
Fence
20'-0"
Drainage
Roof eave line
Drainage
Auger
PAVED LOT
PAVED LOT
56'-0"
4" Concrete Slab
4" Concrete Slab
50'
5'-0"
50'
Water
Water
HOLDING PEN
32'
Loading Chute
32'

FIGURE VII-3. PLAN VIEW OF EXAMPLE FEEDLOT.

Electric motor efficiencies range from 65 to 85 percent, with additional losses in the drive train. There are 1.341 KWH per HP-hr.

Example Problem

Capital Cost Estimation. In this final section, capital costs for an existing feedlot plan are estimated, using the tabulated information and cost estimation techniques outlined in previous sections. Next, using the information given in Section VI, three alternative wastes management systems are designed. Finally, capital and operating costs for the three systems are computed and compared. The calculations of this example will assist the reader in applying the information to his own situation.

The 100-head feedlot plan used in this example is taken from Feedlot Management, August 1971. A perspective drawing of the paved lot is shown in Figure VII-1; Figure VII-3 shows a dimensioned plan view. Because not all construction details are given, some assumptions are made in the sample calculations.

Cost Estimate of Housing and Feeding Facilities. Calculation of capital costs for the housing facility and feeding equipment is shown in Table VII-19. For each item, cost data, its date and source, and quantity required are listed. A comment column details cost adjustments made (using techniques discussed in the section on "Use of Economic Data for Cost Estimation") and notes any assumptions made. The cost estimate is made for January 1972.

Design of Wastes Management System Alternatives. The paved lot surface suggests the use of a liquid or slurry waste handling system. With the information given in Section VI, Liquid and Slurry Wastes Technology, three alternative systems will be designed: (a) anaerobic storage tank, tractor-scraped lot, and field disposal by injection; (b) anaerobic lagoon, tractor-scraped lot, and disposal by irrigation; and (c) aerated lagoon, tractor-scraped lot, and disposal by irrigation.

TABLE VII-[illegible]

[illegible] CAPITAL COST ESTIMATE OF FEEDLOT PLAN

[illegible]	[illegible] Required	[illegible]	Comment	Updated Capital Cost	Estimated Labor Cost	Total Cost Estimate [illegible]
[illegible]	Approx. [illegible] yd³ including [illegible]	$0.[illegible]-$0.[illegible]/yd³ Incl. labor (1968) Table VII-14	The construction cost index includes labor, so using 1968 index and assuming $0.33/yd³ $0.33 $\frac{1640}{1150}$ = $0.47/yd³			$1[illegible]
[illegible]	Approx. 2800 yd³	$0.25-$0.38/yd³ Incl. labor (1968) Table VII-14	$0.25 $\frac{1640}{1150}$ = $0.356/yd³			$[illegible]
Footings	145 Lin. Ft	$25/yd³ concrete including excavation, forming, and backfill (1964) Table VII-9	Estimate 0.1 yd³ of concrete / linear foot of footings $25/yd³ (0.1 $\frac{yd^3}{ft}$) (145 ft) ($\frac{1640}{925}$			$64[illegible]
Post Footings	6	$1.00/hole + $1.50/footing (1971) Table VII-9	6 ($2.50) $\frac{1640}{1575}$			$16
Walls	1450 ft² (10 Ft. Walls)	$1.10/ft² Incl. labor (1964) Table VII-9	1450 ($1.10 $\frac{1640}{925}$			$2820
Poles	6-8" Diam. Treated (11 ft)	$0.69/lin. ft (1971) Table VII-9	6 (11) ($0.69) $\frac{1640}{1576}$ Estimate 30% labor cost	$47	$14	$61
Roof [illegible] Steel	2310 Ft²	$0.52/ft² incl labor (1964) Table VII-9	$0.52 $\frac{1640}{925}$ 2310 includes trusses, purlins, roofing		-	$2120
Pavement	8000 Ft²	$0.45/ft² (1971) Table VII-9	$0.45 $\frac{1640}{1575}$ 8000 add 30% estimated labor cost	$3740	$1120	$4860

TABLE VII-19 (CONTINUED)

Item	Size and/or Quantity Required	Cost (Date) Table	Comment	Updated Capital Cost	Estimated Labor Cost	Total Item Cost Estimated (Jan. 1972)
Fence (Wood)	284 Ft.	\$1.25/Lin. Ft. incl labor (1971) Table VII-9	\$1.25 (284) $\frac{1640}{1575}$	---	---	\$370
Gates	3-12 Ft.	Not Given in Tables	Estimate \$25. Ea. plus 30% labor	\$75	\$23	\$98
Silos Plus Unloaders	2 - 20 x 50 Concrete tower type	\$7,100 Ea. from Manufacturers Literature (1971)	\$7100 (2) $\frac{1640}{1575}$ installed cost	---	---	\$14800
Feedbunk (Slipform concrete)	54 Ft.	\$6.25/Lin. Ft. incl. labor (1971) Table VII-11	\$6.25 (54) $\frac{1640}{1575}$	---	---	\$350
Auger (9 inch diam. less drive	90 Ft.	\$9-11/ft. (1971) Table VII-11	\$10 (90) $\frac{1640}{1575}$ plus estimated 15% labor	\$935	\$140	\$1075
Motor Drive	5 HP	\$400-\$700 Ea. (1971) Table VII-11	\$550 $\frac{1640}{1575}$ plus estimated 20% labor, wiring, etc.	\$570	\$115	\$685
Waterer	2	\$300 Ea. including Heater, plumbing, slab, (1971) Table VII-11	\$300 (2) $\frac{1640}{1575}$	---	---	\$625
Loading Chute	1	Estimate \$300 Total Cost	---	---	---	\$300
					Housing-Feeding Total for facilities	\$37,220

Anaerobic Storage Tank System. In design of the system, it is assumed that a maximum of three months' storage of wastes will be required; for this period a design precipitation load of 15 inches is assumed. A further assumption (having no particular tank construction plan) is that 10 percent of the required storage volume is unavailable because of head space, baffles, etc.

From Section IV, Equation IV-2, and Section VI, Equation VI-2, total tank volume is computed as follows:

Storage for animal wastes:

$$1.0 \frac{\text{ft.}^3}{\text{head-day}} \text{ (90 days) (100 head)} = \quad 9000 \text{ ft.}^3$$

Storage for rainfall runoff from the lot area is calculated as follows:

$$\text{(15 inches)(1/12 ft./in.)(5670 ft.}^2\text{ in pen)} = \quad 7080 \text{ ft.}^3$$

$$\text{Assuming 10\% ineffective volume} = \quad 1608 \text{ ft.}^3$$

$$\text{Then the total storage volume required} = \quad 17688 \text{ ft.}^3$$

This tank (approximately 132,000 gal.) is too large for effective mixing but can be built in two or more smaller compartments. Location of the tank at or under the lower end of the pens will require no additional surface concrete work. A 3000 gallon pull-type, combination spread-injector (the largest size) will be used, requiring approximately 40 trips to the field to empty the tank. A 1400 gpm chopper-type pump will be used for both agitation and filling the tank wagon.

Anaerobic Lagoon System. For design of this system, the same hypotheses of three months' storage and 15 inches of precipitation are made, with the additional assumption of a mild winter climate.

Volume of the lagoon is calculated using Equations VI-7, 8, 9 and 10, presented in Section VI, "Anaerobic Lagoon Storage," as follows:

Liquid storage:

$$(100 \text{ head})\ (7\frac{\text{lb. VS}}{\text{head-day}})/(0.0067\frac{\text{lb. VS}}{\text{ft.}^3\text{ day}}) = 104{,}500 \text{ ft.}^3$$

Solids storage:

$$(7\frac{\text{lb. VS}}{\text{head-day}})(100 \text{ head})\ (90 \text{ days})/20\frac{\text{lb.VS}}{\text{ft.}^3} = 3{,}150 \text{ ft.}^3$$

$$\text{Total storage volume} = 107{,}650 \text{ ft.}^3$$

A two-foot freeboard will be incorporated into the design to handle stormwater and lot runoff. Assuming that a 17-foot total depth will be needed (15-foot effective storage plus 2-foot freeboard), a square lagoon shape, and 3:1 side slopes, Equation VI-7 can be used to estimate the total lagoon volume of 123,430 ft.^{3}

Use of the tractor-scraper for lot cleaning requires that some means be provided for loading with wastes and channeling of rainfall runoff. Assuming that the lagoon is located at the lower end of the lot, an 8-foot wide, 60-foot long concrete ramp will be used, with lot slope adjusted for this purpose. A recirculating pump will be used to mix the lagoon contents for unloading and will be used in combination with a manure gun (plus 1/8 mile of hose) for irrigation.

Aerated Lagoon System. The same assumptions are made in design for this system as for design of the anaerobic lagoon. Again, the tractor-scraper is used to clean the lot daily, with access to the lagoon via a ramp.

From Equations VI-8 through VI-10, the effective storage volume is calculated assuming an average animal weight of 900 lb. over the growing period:

Liquid storage:

$$(100 \text{ head}) \left(900 \frac{\text{lb.}}{\text{head}}\right) \left(0.75 \frac{\text{ft.}^3}{\text{lb.}}\right) = 67{,}500 \text{ ft.}^3$$

Solids storage:

$$(90 \text{ days}) (100 \text{ head}) \left(7 \frac{\text{lb. VS}}{\text{head-day}}\right) / \left(13 \frac{\text{lb. VS}}{\text{ft.}^3}\right) = 4{,}840 \text{ ft.}^3$$

$$\text{Total storage volume} = 72{,}340 \text{ ft.}^3$$

If one chooses a square shape, 3:1 side slopes, and a 17-foot total depth with two-foot freeboard, Equation VI-7 yields a total excavated volume of 84,260 ft.^{3}

Using an aeration rate of 2.0 lb. oxygen/head-day (i.e., constant aeration of the lagoon) and assuming an aerator efficiency of 2.0 lb. oxygen transferred per HP-hr., necessary aerator horsepower is calculated by:

$$2.0 \frac{\text{lb. oxygen}}{\text{head-day}} (100 \text{ head}) \frac{1}{24} \frac{\text{day}}{\text{hours}} / 2.0 \frac{\text{lb. oxygen}}{\text{HP-hr.}} = 4.16 \text{ HP}$$

At 66 percent efficiency, a 7.5 HP aerator will be used. An agitation-irrigation disposal system similar to that of the anaerobic lagoon will be used for this alternative also.

Capital and Operating Costs of Alternative Wastes Management Systems

Using data from the tables of this section and cost adjustment techniques, comparative capital cost estimates for the three systems are made. In addition, estimates of operating costs for the 90-day storage and subsequent disposal are included for each system.

Anaerobic Storage Tank System. Capital costs for the system are summarized in Table VII-20. The tractors, which are multi-purpose machines, could logically have only a portion of their purchase price allocated to the capital cost of the system; however, the total prices are included here to simplify the examples.

TABLE VII-20

CAPITAL COSTS FOR ANAEROBIC STORAGE TANK SYSTEM

Item	Size and/or Quantity Required	Cost (Date) Table	Comment	Updated Capital Cost	Estimated Labor Cost	Total Item Cost Estimate (Jan. 1972)
Storage Tank Poured Concrete	654 yd.^{3}	\$28/yd.^{3} (1964) Table VII-8	654 (\$28) $\frac{1640}{925}$	---	---	\$32,400
Chopper-type Pump-Agitator	1400 gpm	\$1433 (1971) Table VII-4	\$1433 $\frac{1640}{1575}$	---	---	\$1,490
Pull type Spreader Injector	3000 gal	For a 1400 gal. model, \$2,894 (1971) Table VII-4	Employing the 0.6 factor Rule and updating: \$2894 $\left(\frac{3000}{1400}\right)^{0.6}$ $\frac{1640}{1575}$	---	---	\$4,740
Excavation	644 yd.^{3}	\$1.50-\$1.75/yd.^{3}	\$1.50 (654) $\frac{1640}{1150}$	---	---	\$1,400
Tractor	38 HP	\$4200 (1971) Table VII-6	\$4200 $\frac{1640}{1575}$ 10% use	---	---	*\$ 43[illegible]
Scraper Blade	6 Ft.	\$245 (1971) Table VII-5	\$245 $\frac{1640}{1575}$	---	---	\$ 254
Tractor	70 HP	\$7900 (1971) Table VII-5	\$7900 $\frac{1640}{1575}$ 10% use	---	---	*\$ 820
			Total for Anaerobic Tank Storage System			\$41,540

*These items would be used in other farming operations the remaining 90% of the time.

In computing an operating cost estimate, a hauling distance of one-eighth mile was assumed, with one-half hour total round-trip time. Also, a half-hour daily lot scraping was hypothesized (this is not a factor in comparison of the three systems, since the lot is scraped daily in each). A summary of operating cost calculations and assumptions is given in Table VII-21.

Anaerobic Lagoon System. Capital costs for the anaerobic lagoon system and operating costs for the 90-day storage period and disposal operations are summarized in Tables VII-22 and VII-23, respectively.

Aerated Lagoon System. Capital costs for the aerated lagoon system and operating costs for the 90-day storage period and disposal operations are summarized in Tables VII-24 and VII-25, respectively.

Comparison of Example Wastes Handling Alternatives

Of the three alternatives examined in this example, the storage tank can be immediately eliminated on the basis of capital cost, over 60 percent of which is invested in the tank itself. Capital costs for the anaerobic and aerated lagoons are essentially identical, with the aerator cost of the aerated lagoon balanced against the cost of the larger anaerobic lagoon storage volume.

For all three systems, operating costs for the 90-day storage and disposal period are a small fraction of the capital cost (see Table VII-26 for comparison). Focusing on the two feasible alternatives, the odor control afforded by the aerated lagoon doubles the operating cost of the anaerobic lagoon; however, a lower aeration rate might be used (see Section VI). In addition, the aerated wastes will have a lower fertilizer value than the anaerobic effluent. In choosing between these two systems, non-economic considerations (nuisance control, timeliness of operations, etc.) will likely be the deciding factors.

TABLE VII-21

OPERATING COSTS FOR ANAEROBIC STORAGE TANK SYSTEM

Item	Hours of Operation	Comment	Operating Cost (90-Day Storage plus Disposal)
Scraping Labor	0.5 Hr./Day (90 Days)	Rate: $2.50/Hr.	$112.50
Scraping: Fuel and Lubrication	0.5 Hr./Day (90 Days)	Fuel Cost from Eqn. VII-3 plus 15% Lube Cost 38 HP Gas Tractor	$ 33.30
Pumping and Agitation (PTO Drive of 38 HP Tractor)	25 Hr.	Constant Agitation Before and During Disposal	$ 18.50
Hauling and Disposal Labor	20 Hr.	0.5 Hr./Trip, 40 Trips, $2.50/Hr.	$ 50.00
Hauling and Disposal: Fuel and Lubrication	0.5 Hr./Trip (40 Trips)	Fuel Cost from Eqn. VII-3 plus 15% Lube Cost 70 HP Diesel Tractor	$ 15.80
		Total Operating Cost	$229.30

TABLE VII-22

CAPITAL COSTS FOR ANAEROBIC LAGOON SYSTEM

Item	Size and/or Quantity Required	Cost (Date) Table	Comment	Updated Capital Cost	Estimated Labor Cost	Total Item Cost Estimate (Jan. 1972)
Lagoon	107,650 Ft.³ (805,000 Gal.)	1.2¢/Gal. of Capacity (1971) Table VII-8	Assume 1.5¢/Gal. (805,000) ($0.015) $\frac{1640}{1575}$	---		$12,560
Ramp	8 x 60 Ft	$0.45/Ft.² (1971) Table VII-12	$0.45 $\frac{1640}{1575}$ (480) Plus 30% Labor	---	---	$ 292
Tractor	35 HP	$4200 (1971) Table VII-5	$4200 $\frac{1640}{1575}$ 10% use	---	---	*$ 437
Scraper Blade	6 Ft	$245 (1971) Table VII-5	$245 $\frac{1640}{1575}$	---	---	$ 254
Manure Gun + 1/8 Mile Hose	1	$5000 (1972) Table VII-4	5 Hp winch drive, no pump	---	---	$ 5,000
Centrifugal Pump	500 gpm	$890 (1964) Table VII-6	$890 $\frac{1640}{925}$	---	---	$ 1,575
Gasoline Engine and Frame	75 HP	$800 (1972)	Estimate based on automotive engine costs	-	---	$ 800
Irrigation Pipe	1/8 mile	$0.85-$1.25/Ft. 6"-10" Diam (1972) Table VII-6	Assume $1.00/Ft	---	---	$ 600
			Total for Anaerobic Lagoon System			$21,515

*This item would be used in other farming operations the remaining 90% of the time.

TABLE VII-23

OPERATING COSTS FOR ANAEROBIC LAGOON SYSTEM

Item	Hours of Operation	Comment	Operating Cost (90-day Storage plus Disposal)
Scraping Labor	0.5 Hr./Day (90 days)	Rate: $2.50/Hr.	$112.50
Scraping Fuel and Lubrication	0.5 Hr./Day (90 days)	Fuel Cost from Eqn. VII-3 plus 15% Lube Cost 38 HP Gas Tractor	$ 33.30
Pumping and Agitation	36 Hr.	Fuel Cost from 8.5 HP-Hr./Gal. at Operating HP 55% of Maximum. 15% Lube Cost.	$ 44.20
Winch Motor	30 Hr.	Fuel Cost from 8.5 HP-Hr./Gal. at Operating HP 55% of Maximum 15% Lube Cost.	$ 2.25
Labor Costs Moving Gun	Estimate Once each 8 Hr. (4 Moves)	Estimate 1/2 Hr. Labor Per Move at $2.50/Hr.	$ 5.00
			$197.25

TABLE VII-24

CAPITAL COSTS FOR AERATED LAGOON SYSTEM

Item	Size and/or Quantity Required	Cost, Date, Table	Comment	Updated Capital Cost	Estimated Labor Cost	Total Item Cost Estimate (Jan. 1972)
Aerated Lagoon	[illegible]	[illegible] Gal. of Capacity (1971) Table VII-8	Assume 1.5¢/Gal (541,000) ($0.015) $\frac{1640}{1575}$	---	---	$ 8,440
Aerator	[illegible] HP	[illegible] for 5 HP Aerator (1969) Table VII-8	$2500 $\left(\frac{7.5}{5.0}\right)^{0.6}$ $\frac{1640}{1250}$	--	---	$ 4,175
[illegible]	[illegible]	$0.45/Ft (1971) Table VII-12	$0.45 $\frac{1640}{1575}$ (480) Plus 30% Labor	$225	$67	$ 292
[illegible]	[illegible] HP	$4200 (1971) Table VII-5	$4200 $\frac{1640}{1575}$ 10% use	---	---	*$ 436
Scraper Blade	[illegible]	[illegible] (1971) Table VII-5	$245 $\frac{1640}{1575}$	---	---	$ 254
Manure Tank and [illegible]	1	[illegible] (1972) Table VII-4	5 Hp winch drive, no pump		---	$ 5,000
Centrifugal Pump	[illegible] gpm	[illegible] (1964) Fig. VII-[illegible]	$840 $\frac{1640}{425}$	-	---	$ 1,575
Gasoline Engine and Frame	[illegible] HP	[illegible] (1972)	Estimate based on automotive engine costs		---	$ 800
Irrigation Pipe	[illegible]	$0.45-$1.25/Ft [illegible] Diam. (1972) Table VII-4	Assume $1.00/Ft			$ 660
			Total for Aerated Lagoon System			$21,632

*This item would be used in other farming operations the remaining 90% of the time.

TABLE VII-25

OPERATING COSTS FOR AERATED LAGOON SYSTEM

Item	Period of Operation	Comment	Operating Cost (90-Day Storage plus Disposal)
Scraping Labor	0.5 Hr./Day (90 days)	Rate: $2.50/Hr.	$112.50
Scraping Fuel and Lubrication	0.5 Hr./Day (90 days)	Fuel Cost from Eqn. VII-3 plus 15% Lube Cost 30 HP Gas Tractor	$ 33.30
Pumping and Agitation	21 Hr.	Fuel Cost from 8.5 HP-Hr./Gal. at Operating HP 55% of Maximum 15% Lube Cost	$ 25.80
Winch Motor	19 Hr.	Fuel Cost from 8.5 HP-Hr./Gal. at Operating HP 55% of Maximum 15% Lube Cost.	$ 1.72
Labor Costs Moving Gun	Estimate Once each 8 Hr. (3 Moves)	Estimate 1/2 Hr. Labor Per Move at $2.50/Hr.	$ 3.75
Aerator	90 Days	2¢/KWH	245.00
			$422.07

TABLE VII-26

COMPARISON OF EXAMPLE SYSTEMS

System	Investment Costs	90-Day Operating Costs
Anaerobic Storage Tank	$41,540	$229.30
Anaerobic Lagoon	$21,515	$197.25
Aerated Lagoon	$21,632	$422.07

REFERENCES

1. Anon., "Materials Prices," *Engineering News Record*, Vol. 185, No. 7, pp. 40-41 (1970).
2. Anon., "Materials Prices," *Engineering News Record*, Vol. 185, No. 9, pp. 36-37(1970).
3. Anon., "Wage Rates for Key Construction Trades," *Engineering News Record*, Vol. 185, No. 10, pp. 28-29 (1970).
4. Anon., "Check These Points Before You Pave With Concrete," *Feedlot Management*, Vol. 13, No. 8, pp. 20-22, 62 (1971).
5. Anon., "Heil Dehydration Systems," The Heil Company, Milwaukee, Wisconsin, 4 pp. (1971).
6. Anon., 56th Annual Redbook, *Implement and Tractor*, Vol. 87, No. 3, pp. A-81 - B-106 (1972).
7. Anon., "ENR Cost Indexes," *Engineering News Record*, Vol. 188, No. 1, pp. 45-47 (1972).
8. Anon., Unpublished EPA Preproposal (1972).
9. Bainer, R., R. A. Kepner, and F. L. Barger, *Principles of Farm Machinery*, John Wiley and Sons, Inc., New York, 571 pp. (1955).
10. Barre, H. J., and L. L. Sammet, *Farm Structures*, John Wiley and Sons, Inc., New York, 650 pp. (1950).
11. Berge, O. I., E. G. Bruns, T. J. Brevik, and L. A. Brooks, "Considerations in Selecting Dairy Manure-Disposal Systems," in *Proceedings of Farm Animal Waste and By-Product Management Conference*, University of Wisconsin Cooperative Extension Service, p. 58, (1969).
12. Bowers, Wendell, *Modern Concepts of Farm Machinery Management*, Stipes Publishing Company, Champaign, Illinois, 60 pp. (1970).

13. Butchbaker, A. F., J. E. Garton, G. W. A. Mahoney, and M. D. Paine, "Evaluation of Beef Cattle Feedlot Waste Management Alternatives," Final Report, Grant 13040 FXG, EPA (1971).

14. Easler, G. A., "Economic Evaluation of Liquid Manure Systems for Free Stall Dairy Barns," in Animal Waste Management, Cornell University Conference on Agricultural Waste Management, Cornell University, Ithaca, New York, pp. 401-406 (1969).

15. Frevert, R. K., G. O. Schwab, T. W. Edminster, and K. K. Barnes, Soil and Water Conservation Engineering, John Wiley and Sons, Inc., New York, 479 pp. (1955).

16. Guthrie, K. M., "Capital Cost Estimating," Chemical Engineering, Vol. 76, No. 6, pp. 114-142 (1969).

17. Jelen, F. C., Editor, Cost and Optimization Engineering, McGraw-Hill Book Company, New York, 490 pp. (1970).

18. Loehr, R. C., "Pollution Implications of Animal Wastes--A Forward Oriented Review," U. S. Department of Interior, FWPCA, Robert S. Kerr Water Research Center, Ada, Oklahoma, 175 pp. (1968).

19. Mayes, H. F., "Dehydration of Animal Wastes," American Society of Agricultural Engineers Paper No. MC-71-805, Mid-Central Regional Meeting, St. Joseph, Missouri, 14 pp. (1971).

20. McKenna, M. F. and J. H. Clark, "The Economics of Storing, Handling, and Spreading of Liquid Hog Manure for Confined Feeder Hog Enterprises," in Relationship of Agriculture to Soil and Water Pollution, Proceedings of Cornell University Conference on Agricultural Waste Management, Cornell University, Ithaca, New York, pp. 98-110 (1970).

21. Mills, H. E., "Costs of Process Equipment," Chemical Engineering, Vol. 71, No. 6, pp. 133-156 (1964).

22. Morris, W. H. M., "Economics of Waste Disposal from Confined Livestock," in Livestock Waste Management and Pollution Abatement, Proceedings of the International Symposium on Livestock Wastes, American Society of Agricultural Engineers, pp. 195-196 (1971).

23. Nordstedt, R. A., H. J. Barre, and E. P. Taiganides, " A Computer Model for Storage and Land Disposal of Animal Wastes," in Livestock Waste Management and Pollution Abatement, Proceedings of the International Symposium on Livestock Wastes, American Society of Agricultural Engineers, pp. 30-33 (1971).

24. Owens, T. R., and W. L. Griffin, "Economics of Water Pollution Control for Cattle Feedlot Operations," in Proceedings of the 8th Industrial Water and Wastewater Conference, Lubbock, Texas, pp. 82-106 (1968).

25. Shuyler, L. R., "Design for Beneficial Use of Feedlot Runoff," Unpublished M. S. Thesis, Kansas State University, Manhattan, Kansas (1969).

26. Surbrook, T. C., J. S. Boyd, H. C. Zindel, "Drying Animal Waste," in Poultry Pollution: Problems and Solutions, Research Report 117, Michigan State University Agricultural Experiment Station, East Lansing, Michigan, pp. 16-20 (1970).

27. Tinsley, W. A., "Rates for Custom Work in Michigan," Cooperative Extension Service Bulletin E-458, Michigan State University, East Lansing, Michigan, 6 pp. (1970).

28. Trimble, R. L., L. J. Conner, and J. R. Brake, Editors, "Michigan Farm Management Handbook-1971," Report No. 91, Department of Agricultural Economics, Michigan State University, East Lansing, Michigan, 92 pp. (1971).

29. Van Dam, J., and C. A. Perry, "Manure can be Processed and Sold at a Profit," The Practicing Nutritionist, Vol. 3, No. 4, pp. 40-42 (Undated).

30. Van Dam, J., and C. A. Perry, "Manure Management - Costs and Product Farms," California Agriculture, pp. 12-13 (December 1968).

31. Wilmore, R., "Labor-free Manure Disposal?" Farm Journal, pp. 26C-26D (August 1969).

APPENDIX TABLE VII-1

DRAGLINE CAPACITIES (15)

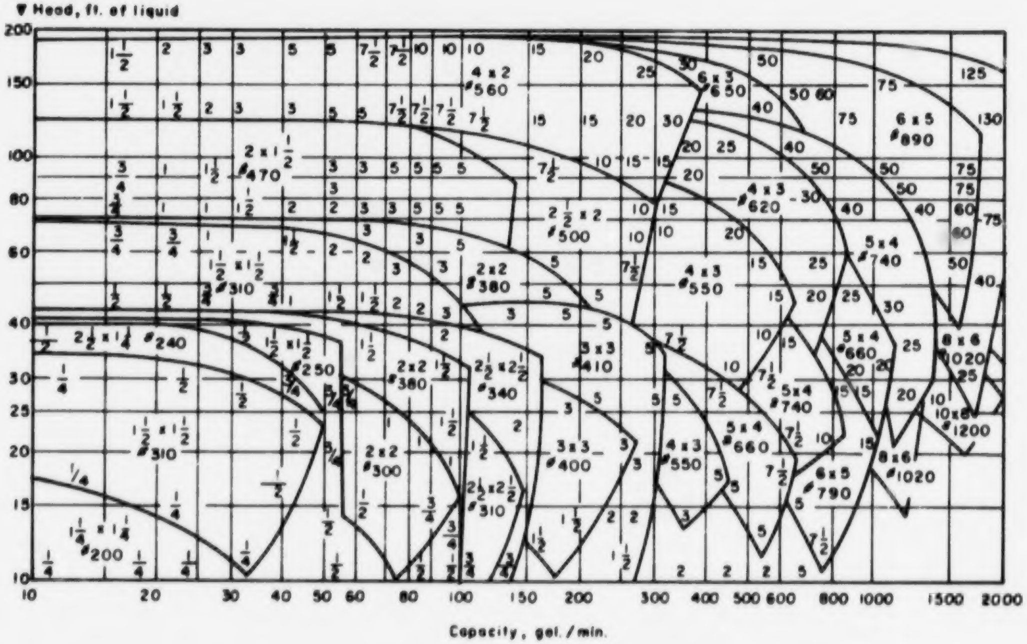
DRAGLINE CAPACITY AND OPTIMUM DEPTH OF CUT*

Class of Material	3/8	1/2	3/4	1	1 1/4	1 1/2	1 3/4	2	2 1/2
Light moist clay or loam	5.0† 70‡	5.5 95	6.0 130	6.6 160	7.0 195	7.4 220	7.7 245	8.0 265	8.5 305
Sand or gravel	5.0† 65‡	5.5 90	6.0 125	6.6 155	7.0 185	7.4 210	7.7 235	8.0 255	8.5 295
Good common earth	6.0† 55‡	6.7 75	7.4 105	8.0 135	8.5 165	9.0 190	9.5 210	9.9 230	10.5 265
Clay, hard, tough	7.3† 35‡	8.0 55	8.7 90	9.3 110	10.0 135	10.7 160	11.3 180	11.8 195	12.3 230
Clay, wet, sticky	7.3† 20‡	8.0 30	8.7 55	9.3 75	10.0 95	10.7 110	11.3 130	11.8 145	12.3 175

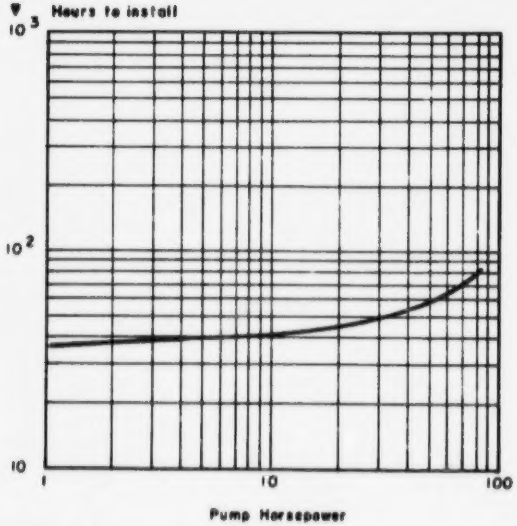
*From Power Crane and Shovel Association, Proper sizing of excavators and Hauling Equipment, Tech. Bull. 3 (1949).

†Upper line is optimum depth of cut in feet.

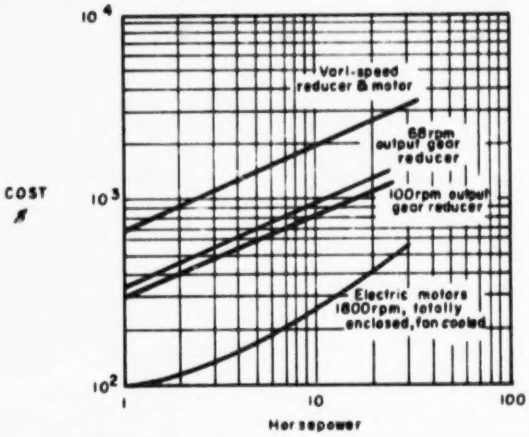
‡Lower line is the capacity in cubic yards per hour for grade level loading and 90 degree swing.



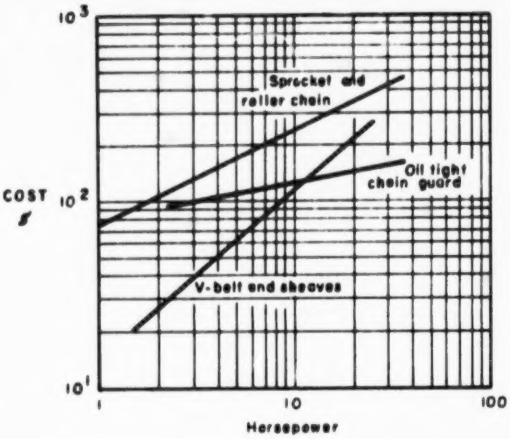
APPENDIX FIGURE VII-1. PUMPS: GENERAL PURPOSE CENTRIFUGAL (single and two-stage, single suction) (21).



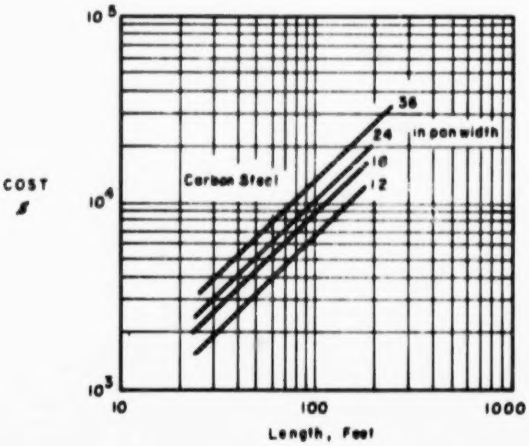
APPENDIX FIGURE VII-2. PUMPS: INSTALLATION TIME (man-hr. to install pump and motor) (21).



APPENDIX FIGURE VII-3.
INVESTMENT COSTS OF MOTORS.



APPENDIX FIGURE VII-4.
INVESTMENT COSTS OF DRIVE UNITS.



APPENDIX FIGURE VII-5. INVESTMENT COSTS OF VIBRATING CONVEYORS.

SECTION VIII

FEEDLOTS AND SOCIETY IN A COEXTENSIVE ENVIRONMENT

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SECTION VIII

FEEDLOTS AND SOCIETY IN A COEXTENSIVE ENVIRONMENT

PROBLEMS OF COEXISTENCE

An increasing number of complaints, claiming encroachment upon individual rights and property damages resulting from pollution and defilement of environmental quality, are being filed against feedlots by neighbors and the populace of nearby communities. Some of these complaints have resulted in judgments against the involved feedlots. Prevention of such complaints is a major concern in the selection of new feedlot sites and the management of new and existing feedlots. The aspects of site selection related to reduction of environmental pollution are discussed in Section III. Additionally, a good-neighbor policy should be initiated for both new and existing feedlots. This policy should include a total operational or management plan designed to eliminate to the greatest extent possible those bases for complaints regarding pollution and other aspects of environmental quality. These plans should incorporate the necessary actions to reduce:

1. transport of pollutants from pen area and field application sites to surface waters in runoff (covered in previous sections);
2. nuisances such as odors, noise, insects, dust, and allergens;
3. air transport of pollutants to surface waters; and
4. transmission of diseases.

Public Relations

According to Moorman (17), problems which arise from beef feeding operations can become a source of community trouble due to the following conditions:

1. an unawareness of existing problems on the part of feedlot management and laborers who, over a period of years, become accustomed to the environmental conditions which exist on and near feedlots;

2. a communication gap between feedlot management and people in the surrounding area resulting in a lack of management insight concerning the importance of a problem to neighbors and the community; and
3. a negative attitude on the part of the community regarding the manager's efforts to alleviate the conditions which contribute to a problem.

To prevent these situations from occurring, a positive, cooperative approach is needed. This approach may include a well organized program of public relations. Public awareness of feedlot problems and of management's concern for minimizing unpleasant situations can lead to a less critical public attitude regarding those aspects of lot operation which cannot, at present, be subjected to total control.

Essentials of Public Relations Program. Four basic essentials of a well organized public relations program have been reported by Steen (20): (a) Inform the public of the basic problems encountered in feedlot operation. Make clear the severity of these problems. (b) Inform the public of the present efforts being made toward solving these problems. Such presentations should emphasize the sincerity of feeders toward correcting pollution problems. (c) A give and take relationship must be developed between feeders and the public. This maintains a vital contact through which the feeder can identify potential problems. Awareness of potential problems, their causes, and corrections should be maintained at all times. Thus, direct firsthand knowledge can be given when oral complaints are received. (d) Develop a public relations group in feeders organizations which can coordinate and methodically present the message to the public. One individual cannot present the total picture and can be overwhelmed by statements of less informed observers.

Reaching the Public. Feeders can relay their message through the mass media and popular press (farm reports on radio and television or magazines which are oriented toward the rural community will not reach the urbanites). Guest speaking engagements at social, service, and civic-oriented clubs and meetings will stimulate dialogue between the public and the feeders. Pre-planned, open-invitation, annual or semi-annual open houses on the feedlot will create better understanding of feedlot operation, problems, and their solutions. In some areas, feedlot owners have collectively co-sponsored an open invitation barbecue with local sportsmen's groups on an annual basis (usually these are in conjunction with the opening of a hunting season). A short keynote address given at these events will effectively relay public relations messages.

Conditions Which Compound Public Relations Problems. Adverse public reactions toward the feedlot can make public relations especially important during the time period required to institute pollution controls, regardless of the precautions observed by feedlot management. Relationships generally improve, however, once a pollution control system has been established and its effectiveness is well publicized.

Public relations problems can also arise in areas where feedlots concentrate. In these areas, feedlots which have instituted effective pollution controls are in some cases the recipients of complaints and lawsuits along with nearby feedlots which have shown less concern for environmental quality. This problem may be compounded by industries which have effluents and odors similar to those described for feedlots. Thus, cooperative pollution abatement agreements should be entered into between feedlots and industries located in the same area.

NUISANCE PROBLEMS

Legal Implications of Nuisances

Next to pollution of surface waters, nuisances account for the largest number of complaints and legal actions lodged against feedlots. Pollution of water and air by beef feedlots is a very real problem; however, the circumstances of each case must be considered to determine whether any set condition legally constitutes a nuisance. Judgment of severity of the nuisance is based on the relative interests of the involved parties. In many cases, feedlots have been forced to close because continued operation was found to be economically impractical even if legally allowable after assessment of actual or punitive damages (13).

Types of Legal Nuisances

Nuisances may be divided into two general legal types--public and private. A public nuisance is created when property is used in a manner which interferes with a substantial number of people. A private nuisance is present when property use interferes with the rights of a few. Because the interests of the majority may be greater than the interests of private individuals, an injunction will more likely be granted when a public nuisance is involved.

A second allegation requesting actual and/or punitive damages may accompany many petitions for injunctive relief. Actual damages include out-of-pocket expenses, property losses, and decreases in property values which occur as a result of nuisance. Punitive damages include damage resulting from intentional or malicious conduct. Thus, a feedlot operator or owner could be held liable for punitive damages if he operated a feedlot in such a manner as to cause damage to a neighbor, providing the method of operation could have been altered to prevent such damage at little or no cost.

A set procedure or operational plan to maintain absolute protection under nuisance laws does not exist for the livestock feeder. Thus, it is most imperative to make every attempt to prevent such complaints from arising. Those who follow a good-neighbor policy by trying to avoid causing discomfort or damage to neighbors are less likely to be sued.

Prior operation of the feedlot before urban or residential encroachment is generally taken into consideration by the courts. However, expansion of feedlots after residential development has taken place is likely to cause less favorable considerations of the feeder's problems.

Zoning

Zoning can help alleviate potential problems with nuisance complaints. If an area is zoned for agricultural purposes, presumably, cattle feeding would be well within the limits of approved land uses for that area. However, in many areas, communities and cities have control of agriculturally zoned lands which fall within a specified distance of their perimeters. This distance is generally based on the population of the city. Additionally, a feedlot operator does not have the right to cause damage to or degrade values of neighboring agricultural properties. In some areas, feeders are applying for zoning restrictions which will specify a strict agricultural type of use to discourage residential development or at least reduce the probability of legal actions from those who do establish residences in these zones. Thus, the primary use of zoning in this sense is to keep the number of neighbors at a minimum and to reduce the probability of having the feedlot declared a public nuisance.

Odor Nuisance

Odor is the most controversial, most complained about, and the most uncontrollable nuisance generated from feedlots. There are two basic odors associated with feedlot manure wastes (8):

1. the natural aroma inherent of fresh excreta which is not persistent and dissipates rapidly as the excreta cools, and
2. the offensive putrid odors of gases produced by the biological decomposition of excreta under anaerobic conditions (putrefaction).

The natural odor of fresh excreta is not of great concern as it is not a strong odor and is not offensive to most people. However, the odors produced by the anaerobic decomposition of manure wastes are of major concern. Every attempt should be made to control or eliminate the conditions which cause these odors. The need to control odors is complicated by the current inability to measure odors without predilection. This is due to the extreme sensitivity of the human olfactory senses which detect odors at levels far lower than the levels which can be detected with electronic odor measuring instrumentation. Additionally, humans have varying impressions as to what constitutes an objectionable odor. This can be further complicated by odor fatigue--a condition that arises when a person is exposed to strong odors for a long period of time.

Causes of Odors. The putrid odors from animal wastes are complex mixtures of malodorous gases and organic compounds. Hydrogen sulfide, ammonia, and methane make up the majority of malodorous gases (2) (9) (18). Organic compounds which have been identified as odor producing include alphatic amines, methyl and ethyl mercaptans, organic acids, indole, and skatoles (2) (9).

Chemical Odor Control. Chemicals used to reduce or control the odors of putrefaction include masking agents, counteractants, deodorants, enzymes or bacterial starters, oxidants, and biological inhibitors. Each of these chemical types provides an individual approach to the solution of the problem as follows. Masking agents superimpose a pleasant odor on an unpleasant odor. Counteractants cancel out the olfactory sensation of the odor; in this case, both odors still exist but neither can be smelled. Deodorants destroy odor and leave no smell. Enzymes or bacterial starters alter normal bacterial and/or enzymatic activity, thus inhibiting the production of odor. Oxidants oxidize the fraction of the manure that bacteria thrive on, thus retarding bacterial action through alteration of their food supply and environment. Biological inhibitors kill the bacteria in the wastes, preventing putrefaction and the formation of related malodorous compounds.

Masking agents and counteractants are more effective for control of feedlot odors than deodorants and enzymes or bacterial starters (2) (14).

For animal wastes, odor masking is not completely satisfactory because there is no substitute odor that is completely inoffensive to everyone. In some cases, more complaints are received due to the masking odor than due to manure odors (17). One unidentified masking agent tested was found to be effective but too costly (4). Most chemical odor control test procedures have not, in the past, provided information regarding the aesthetic desirability of chemicals used to eliminate odors.

A dilute water solution of potassium permanganate ($KMnO_4$) was found to be more effective than a variety of odor counteractants, masking agents, and disinfectants, including proprietary compounds applied during all seasons in southern California (8). The application procedure is as follows:

1. Remove manure from the pens at least three times a year and scarify the ground to promote aerobic conditions.
2. Follow scarification with spraying of the ground with a one percent (approximate) solution of potassium permanganate so that each treatment amounts to 20 lb $KMnO_4$ per acre.
3. If "hot" spots develop between regular sprayings, these spots should be resprayed.

The economics of this treatment and the residual effects of added potassium and manganese on the characteristics of the wastes were not reported.

Biological inhibitors have been used to control odors of hog and poultry manure with a limited degree of success. Hydrated lime applied at the rate of 0.16 pounds per 100 pound hog per day and chlorine applied at 0.1 pound of active chlorine per 100 pound hog per day have been shown to retard bioactivity in hog wastes sufficiently to reduce the production of malodorous gases (10). The hydrated lime applications reduced hydrogen sulfide and carbon dioxide production. Chlorine reduced production of ammonia, methane, hydrogen sulfide, and carbon dioxide. Carbon dioxide is not considered a malodorous gas; however, its reduction is an indication of the extent of biological retardation. Paraformaldehyde flake applied at the rate of 1 gram per 100 grams of poultry feces prevented ammonia odor for nine days (19). The presence of chemical odors at the recommended application concentrations was not discussed.

The odor-retarding effect of biological inhibitors is temporary and can be best used to reduce odors in slurries and solid wastes during the periods when they are being removed from storage tanks and lagoons and disposed of by land application.

There has not been a chemical control developed which is both economical and entirely satisfactory to control the putrid odors of feedlot wastes. Management practices which regulate the physical condition of the wastes and utilize mechanical means to minimize odors are, at present, the most practical means of control.

Waste Management to Control Odor. Management practices used to control odors are basically those of good housekeeping. Odors can be significantly reduced by minimizing the conditions which cause their production; these conditions fall into the following categories (17):

1. extended periods of standing water and excessively moist pen conditions due to inadequate drainage;
2. feed spillage around feed bunks and feed mills;
3. improper carcass disposal;
4. excessive accumulation of manure in feed pens; and
5. improperly managed manure storage and disposal operations.

Inadequate drainage can be a result of poor site selection, poor management, or both. Relocation of the feedlot may, in some instances, be the only practical solution to a poor drainage problem. Every attempt should be made to maintain dry pen and solid manure storage areas since the odor producing processes of putrefaction are dependent on a wet anaerobic environment. Spillage and overflow from watering systems should be carefully eliminated, manure should not be allowed to block drainageways, and additional drainage channels should be constructed where necessary.

Feed is an organic material which is subject to the same bacterial processes of putrefaction as manure wastes. Spillage of feed around feed bunks and feed mills should be kept to a minimum because spillage is both wasteful and the cause of odor problems under moist conditions.

Decomposition of animal carcasses begins rapidly and can be a major source of odor. An agreement should be made with a local rendering company to pick up animals on a daily or standby basis. These animals should be removed from the feedlot premises as soon after death as possible.

Feedpens should be cleaned on a regular schedule to eliminate excessive moisture conditions which occur with a heavy manure pack. Pen cleaning is usually scheduled during interim feeding periods when the pens are empty. In feedlots with excessive pen moisture conditions manure removal should be more frequent. This may be accomplished by moving the animals to adjacent pens on a regular rotational schedule with the least amount of disturbance of the animals.

Careful planning and implementation of management programs for waste storage and disposal can reduce odors or the effects of odors on neighbors. Some considerations for a storage/disposal management plan include:

1. covering all anaerobic liquified waste storage tanks or lagoons;
2. considering the use of oxidation ditches for the storage of liquified wastes if volumes are too great to store in covered anaerobic structures;
3. maintaining all manure removal equipment (automated and manual) and making sure that manure pits and storage tanks are cleaned thoroughly and that stockpiles are kept reasonably dry;
4. using only manure transport vehicles that do not spill or leak on roadways;

5. avoiding field spreading manure near residences, close to arterial highways, late in the afternoon, on still days, or on weekends; and
6. incorporating manure spread on the land with the soil.

Odors associated with dust have been controlled successfully in poultry houses by filtering the exhaust from the house through a water spray air scrubber (22). This method has not been used extensively in total confinement beef barns or dairy barns; however, liquid scrubbers may have application in instances where exhaust odors from these operations are associated with dust.

Malodorous compounds such as hydrogen sulfide, and ethyl and methyl mercaptan can be removed from the exhaust air of confinement buildings by passing it through a sterile loam soil filter (3) (5) (9). The volume of soil needed in the filter may be prohibitive for use on a large capacity facility.

Noise Nuisance

Noise is a nuisance which, at the present time, is very controversial in urban areas, especially in the vicinity of airports, railroad lines, and street repairs. The normal sounds of cattle lowing and farm equipment operation have not constituted a serious nuisance. However, continuous high pitch sounds such as fans, dryer units, oxidation rotors, aerators, etc., are more irritating than noises of variable pitch or intermittent duration. Stationary equipment should be mounted on resilient brackets to reduce vibration noises and echoes from resonant building materials. Other sounds which can be annoying to neighbors are the operation of farm equipment and the loading or unloading of cattle at night. Annoying sounds do not travel as far as odors and other nuisances but can create ill-will toward a feedlot which, in turn, lessens tolerance for odors or other nuisances.

Biological Nuisance

Insects, birds, and rodents which breed on or are attracted to feedlots can constitute a serious nuisance. House flies and stable flies lay their eggs in fresh excreta or wet manure applied to the land. As the excreta dries, the larvae or maggots which hatch from the eggs pupate then emerge as adult flies, thus completing their life cycle. After a hatch and with the aid of the wind, adult flies spread over the countryside in search of new breeding grounds. These flies can be both a nuisance and a health hazard to neighbors and residents of nearby communities. Fly infestations can be avoided by timing manure removal so that it does not occur with peak fly breeding periods of the year and by keeping the manure dry to reduce optimum fly breeding conditions the rest of the year (1). Ammonia appears to be an attraction for flies. A one percent paraformaldehyde flake application will reduce ammonia production and effectively control fly infestations (19). Maggots and rodents can be controlled by applying 0.1 pound of active chlorine per 100 pound hog per day to the swine wastes (10).

Since birds and rodents are attracted to feedlots in search of food, elimination of feed spillage, weeds, and carcasses will help reduce infestations. Mosquitos and horseflies propagate in stagnant water and mud flats. Collection ponds and settling basins designed so that they can be drained and the bottom sludges dried out will help eliminate mosquito and horsefly problems.

Dust and Allergen Nuisance

Dust can be a nuisance to those living near feedlots, and civil court actions can be initiated showing negligence or lack of ordinary care to stop wind transported pollutants originating from agricultural practices. These actions usually involve pesticide drift but could include dust (21). Other than basic annoyance from particulate material in the air, dust can be an allergen. Many people react allergenically to pollen, fungal spores, and other components of dust which can originate on feedlots.

Dust problems arise most commonly when feedlot surfaces become too dry. Moisture content of the manure can be increased by increasing the stocking rate. Water sprayed on the alleyways, feed pens, and access roads will reduce dust. Mowing weeds will keep pollen to a minimum.

Aesthetic Quality

Since a psychological victory can be won by mowing weeds and keeping the facility and buildings in repair, a neat, well-maintained facility appearance is a necessity. Vegetative windbreaks can be utilized or placed to double as "visual shelters." A clean, well-kept cultivated grass strip along roads will greatly improve overall appearances. Leaving neighbors and passersby with a desirable impression is important as they will expect a poorly kept place to violate environmental controls.

AIRBORNE NUTRIENTS AND GASES

Odor nuisances caused by the production of malodorous gases and substances are not the only problems created by the processes of putrefaction of feedlot wastes. Evolution of ammonia and hydrogen sulfide gases into the air from these wastes can cause actual property damage. Approximately two-thirds of the ammonia produced in an anaerobic lagoon escapes to the air (12). Thus, enough ammonia can escape from a 0.67 acre anaerobic lagoon in one year to fertilize 60 acres of corn (12). Ninety percent of the nitrogen in urine excreted in a feed yard may escape to the air as ammonia (11). Both of the above conditions can have serious pollutional implications if there is a lake located near a feedlot. In northeastern Colorado, a lake located about 1.25 miles from a 60,000 head feedlot absorbed enough ammonia from the air in one year to raise its nitrogen concentration by 0.6 mg/liter (11). This concentration is approximately twice the critical inorganic nitrogen concentration necessary to support high density populations of algae called "blooms." In northcentral Ohio, hydrogen sulfide gas evolving from a river (about one mile downstream from a refinery waste outfall) caused lead in the white paint on nearby houses to turn black. Legal suits were filed and damages were collected by the owners of these residences; additionally, the refinery was required by court order to correct this situation. The hydrogen sulfide quantities produced by small feeding operations are not significant enough to cause this type of problem; however, care should be exercised in larger lots to prevent management errors which would permit production of sulfide gases in sufficient quantities to cause similar problems.

CONTROL OF DISEASE ORGANISMS

In the cities, controlled sewage disposal and chlorinated water supplies have reduced the incidence of waterborne disease. As a result of control of these diseases, the average citizen has become placid in attitude concerning water and airborne diseases. However, utilization of rural areas for outdoor recreation by city dwellers has been steadily increasing as most people seeking outdoor recreation wish to be near water. Swimming has been predicted to be the most common form of outdoor recreation by the year 2000 (7). Exposure to the environment of domestic and wild animals and surface waters will increase man's exposure to water and airborne diseases. Disease in animals is more prevalent in areas where animals are concentrated, thus feedlots are a possible source of disease in man's environment.

Animal Diseases Transmissible to Man

There are over 100 animal diseases (zoonoses) which can be transmitted between lower vertebrates and man (6). The following is a brief listing of the more common cattle-transmitted zoonoses by major classification of the causative organism (6) (7) (15) (16).

Bacterial Diseases

1. Salmonellosis may be caused by any one of 1,300 isolated serotypes of Salmonella. These organisms are commonly

isolated from cattle feces. In acute cases in calves, 10,000,000 organisms per gram of feces have been reported. The numbers and regularity of occurrence of *Salmonella* downstream from cattle feedlots more than implicates the possibility of occasional or chance human ingestion in recreational waters. Since all *Salmonella* strains or serotypes are considered pathogenic, feedlot runoff must be recognized as potentially implicated with disease (15). *Salmonella* can survive from several weeks to three months in surface and drinking water. In 1966 a large waterborne outbreak of *Salmonellosis* in humans occurred in Riverside, California from a contaminated water supply (6). The source of contamination was not identified; however, it was speculated that contamination occurred by seepage from distant cattle feedlots.

2. *Leptospirosis* is caused by a waterborne spirochaete. In domestic animals these bacteria are found primarily in cattle and swine. During infestation they may be shed in the urine for several months. Counts as high as 100 million leptospires per ml of urine have been reported. The disease can be transmitted nasally, orally, or through abraded or lacerated skin. Leptospires may live in water for several weeks. Both sluggish and fast-moving waters are infectious and increased infectiousness occurs with flooding. In the United States, swimming has accounted for 10 outbreaks that involved 233 human cases (7). In 1964 *Leptospira pomona* was isolated from the swimming site in a creek where human cases occurred (16). This creek was frequented by cattle. In Washington 61 human cases occurred following swimming in water contaminated by infected cattle (7).

3. Anthrax incidence in humans has declined steadily in the past 50 years. However, the spores remain viable for as long as 60 years since anthrax is one of the most resistant pathogenic bacteria. Anthrax is most common in warm climates with alkaline undrained soils and the potential of infection will exist for many years in anthrax contaminated areas.
4. Tetanus is a widespread disease caused by a spore-forming bacteria which is abundant in the feces of humans, horses, and other herbivores which include cattle. Entry of the bacteria into the body is usually through a wound. The spores are persistent in the soil for a number of years and surface water can play a role in the dissemination of Tetanus spores.
5. Brucellosis is a contagious disease of cattle, swine, and goats and occurs in humans. The bacteria Brucella is shed in feces and uterine secretions by infected animals. Infection is usually by direct contact with contaminated wastes; thus, people who work around livestock are generally the most susceptible to brucellosis.

Rickettsial Diseases

Q Fever usually comes into existence as infection in domestic livestock. The disease is related to Rocky Mountain spotted fever and other fevers associated with ticks. The exact mode of transmission of Q Fever has not been determined; however, dust laden air, direct contact with animal wastes, and ticks are considered important. One mode of transmission that has been suggested involved an aerosol created by operating a rain gun or spray irrigation system in a drying wind (16).

Viral, fungal, and parasitical diseases

Viral, fungal, and parasite caused diseases are also zoonotic. Little is known about the relationships between cattle and man involving the transmission of most of these forms of zoonosis. A summary of available information concerning these diseases is compiled in the references listed at the beginning of this discussion.

Prevention of Public Health Hazard

The public health hazard associated with these disease organisms, if they are allowed to contaminate potable water supplies (both private and public) and recreational waters, is sufficient reason to prohibit the entrance of feedlot seepage or runoff into streams or other surface waters. Care should also be exercised to control wind drift from liquid wastes application areas and feedlot dust.

REFERENCES

1. Adolph, R. H., "Schedule Manure Removal to Avoid Fly Breeding," San Diego Poultry Notes, November 19, 1970.

2. Burnett, W. E., and N. C. Dondero, "Control of Odors from Animal Wastes," Transactions of the A.S.A.E., Paper No. 68-909, pp. 221-224 (1970).

3. Burnett, W. E., and N. C. Dondero, "Soil Filtration to Remove Odors," Odors, Gases and Particulate Matter from High Density Poultry Management Systems as they Relate to Air Pollution, New York State Dept. of Health, Division of Air Resources, Contract No. C-1101, April 1969.

4. Burnett, W. E., and B. Gormel, "Odor Control by Chemical Treatment," Odors, Gases, and Particulate Matter from High Density Poultry Management Systems as they Relate to Air Pollution, New York State Dept. of Health, Division of Air Resources, Control No. C-1101, April 1969.

5. Carlson, D. A., and R. C. Gumerman, "Hydrogen Sulfide and Methyl Mercaptan Removals with Soil Columns," Proceedings of Twenty-first Industrial Wastes Conference, Purdue University, Lafayette, Indiana Part, 171-191 (1966).

6. Decker, W. M., and J. W. Steele, "Health Aspects and Vector Control Associated with Animal Wastes," Management of Farm Animal Wastes, Michigan State University, East Lansing, Michigan, A.S.A.E. Publication No. SP-0366, pp. 18-20, May 1966.

7. Diesch, S. L., "Disease Transmission of Water-Borne Organisms of Animal Origin," Agricultural Practices and Water Quality, Iowa State University Press, Ames, Iowa, First Edition, pp. 265-285 (1971).

8. Faith, W. L., "Odor Control in Cattle Feed Yards," Journal of the Air Pollution Control Association, Vol. 14, No. 11, November 1964.

9. Gumerman, R. C., and D. A. Carlson, "Chemical Aspects of Odor Removal in Soil Systems" Animal Waste Management, Proceeding of Cornell University Conference on Agricultural Waste Management, Syracuse, New York, pp. 292-302, January 1969.

10. Hammond, W. C., D. L. Day, and E. L. Hansen, "Can Lime and Chlorine Suppress Odors in Liquid Hog Manure?" Agricultural Engineering, pp. 340-343, June 1968.

11. Hutchinson, G. L. and F. G. Viets, Jr., "Nitrogen Enrichment of Surface Water by Absorption of Ammonia Volatilized from Cattle Feedlots," Science, Vol. 166, pp. 514-515 (1969).

12. Koelliker, J. K. and J. R. Miner, Desorption of Ammonia from Anaerobic Lagoons, A.S.A.E. Paper No. MC-71-804, April 1970.

13. Levi, D. R., and J. C. Holstein, "Stockmen's Liability Under the Missouri Nuisance Law," Science and Technology Guide, University of Missouri, Columbia Ext. Div., File: Ag. Econ. 3 3/70 719 (1970).

14. Ludington, D. C., "Odors and Their Control," Agricultural Waste Principles and Guidelines for Practical Solutions, Cornell University Conference on Agricultural Waste Management, Syracuse, New York, pp. 130-136, February 1971.

15. Miner, J. R., L. R. Fina, and C. Piatt, "Salmonella infantis in Cattle Feedlot Runoff," Applied Microbiology, pp. 627-628, May 1967.

16. Rankin, J. D., R. J. Taylor, "A Study of Some Disease Hazards Which Could be Associated with the System of Applying Cattle Slurry to Pasture," The Veterinary Record, pp 578-581, November 22, 1969.

17. Moorman, R., Jr., "Controlling Odors from Cattle Feedlots and Manure Dehydration Operations," Journal of the Air Pollution Control Association, Vol. 15, No. 1, January 1965.

18. Schuck, E. A., et al., Identification of Feedlot Odors, DHEW, PHS, Final Report, Grant No. UI 00531-02, 24 pp., April 1969.

19. Seltzer, W., S. G. Moum, and T. M. Goldhaft, "A Method for the Treatment of Animal Wastes to Control Ammonia and Other Odors," Poultry Science, Vol. 48, No. 6, pp. 1912-1918, November 1969.

20. Steen, C. A., "The Public Relations of Agricultural Waste Management," Agricultural Waste in an Urban Environment, Conference Proceedings, Atlantic City, New Jersey, New Jersey Dept. of Ag., Trenton, New Jersey, pp. 174-182, September 1970.

21. Walker, W. R., "Legal Restraints on Agricultural Pollution," Agricultural Engineering, pp. 636-637, November 1970.

22. Willson, G. B., "Control of Poultry House Exhaust Odors," Poultry Digest, pp. 332-334, July 1971.